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User perception-based quantitative studies of Location Based Services of today and tomorrow

Master of Science Thesis

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Subject approved by Council of the
Faculty of Computing and Electrical
Engineering on 06-02-2013

Abstract

Tampere University of Technology
Degree Program in Information Technology, Department of Electronics and Communications Engineering
Noor, Muhammad Tarek Hasan: User perception-based quantitative studies of Location Based Services of today and tomorrow
Master's thesis, 72 pages, appendix 15 pages
September, 2014
Major subject: Communications Engineering
Examiners: Associate Prof. Dr. Elena-Simona Lohan, Dr. Danai Skournetou
Keywords: LBS, user perception, survey, localization technologies, test of significance

Modern Location Based Services (LBS) are not any more limited to navigation or routing services, but they have flourished in every sphere of life whether it is regular activity tracker or family finder. The continuous advancement of location technologies, such as GNSS and cellular in outdoors and WLAN in indoors, opens new challenges for the LBS providers. Due to the emergence of location-enabled smartphone technologies, the use of location based services and applications has increased remarkably in the last few years. This forces the LBS providers to think beyond the boundaries. Therefore, the analysis of the user needs, behavior, perception and preference becomes one of the key factors and eventually prerequisites for success in this sector.

The thesis comprises a *survey* focusing on LBS from different perspectives, such as localization knowledge, privacy concerns and LBS usage, and an *analysis* based on the responses from 118 volunteer participants. The analysis begins with the classification of the users with respect to their "technical knowledge in localization", "privacy concerns" and "LBS usage" based on the survey results, and it continues with the analysis of the correlation and similarity between the user classes. The user classes are compared based on the Mann-Whitney-Wilcoxon, Fligner-Policello and unpaired t-test in terms of preferences similarity. The user perceptions with respect to the cost and feature preferences are also analyzed per user class. The aim of the thesis is to illustrate how the LBS preferences differ among various user classes and how the user classes may correlate. The main findings of the analysis are that the user's background class has a significant impact on the preferences. Moreover, the high-level knowledge users have similar preferences as the high-level usage users, even though the correlation among the user classes is very low. Another interesting finding of this analysis is that the high-level knowledge users are relatively less willing to pay for LBS applications in comparison to the other

user classes. From the privacy-concern based classification, it is observed that most of the users have certain privacy concerns, which represents one of the barriers in the LBS development. Finally, it can be inferred that the statistical analysis and the comparative results justify the empirical user classification derived in this thesis.

Preface

This Master of Science thesis has been done at the Department of Electronics and Communications Engineering in the Faculty of Computing and Electrical Engineering in Tampere University of Technology. The research work of this thesis was financially supported by the Academy of Finland (project 256175) “Cognitive Approaches for Location in Mobile Environments”.

I would like to express my sincere gratitude to Associate Prof. Elena-Simona Lohan for supervising the thesis and providing continuous support whenever I needed. I would also like to thank Dr. Danai Skournetou for helping me with valuable suggestions during the thesis work. I also want to thank the IT services and Student services of Tampere University of Technology for supporting and helping me while conducting the thesis work. I am also deeply thankful to all the respondents’ who have participated in the survey, without whom, this research work wouldn’t have been possible.

I would also like to thank all my friends especially in Tampere for providing wonderful times during my Masters studies. Finally, I am thankful to my parents, Rehana Akter and Md. Nurus Safa, my elder sisters Tania Noor and Dr. Tanita Noor for all the encouragement and motivation.

Tampere, August 10, 2014

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Contents

List of symbols

H_a	alternative hypothesis
H_0	null hypothesis
$L1, L2$	frequency bands in GPS
LF	level of familiarity
LP	level of privacy
LU	level of usage
M, N	number of samples
NOD	number of devices
$PPMC$	Pearson Product-Moment Linear Correlation coefficient
QF	quality factor
RTT	round trip time
S	standard deviation
T_{BS}	time of transmission from base station
T_{UE}	time of transmission from user equipment
U	Mann – Whitney form of statistics
f_0	center frequency
f_s	frequency spacing
n	frequency channel number
p	probability value
per_{kn}	perceived knowledge
t	unpaired t-test output
$true_{kn}$	true knowledge
wt	weight
μ	mean
α	significance level
σ	variance
$\bar{X}$	mean of X
$\hat{P}$	mean of P
ψ	variance

List of Abbreviations

A-GNSS	Assisted GNSS
AOA	Angle of Arrival
BPSK	Binary Phase Shift Keying
BS	Base Station
C/A	Coarse/Acquisition
CDMA	Code Division Multiple Access
CID	Cell ID
CosBOC	Cosine Binary Offset Carrier
CS	Commercial Service
DSSS	Direct Sequence Spread Spectrum
E-CID	Enhanced Cell ID
FDMA	Frequency Division Multiple Access
FP	Fligner-Policello
GEO	Geo Stationary Earth Orbit
GIS	Geographical Information System
GLONASS	Global Orbiting Navigation Satellite system
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICT	Information and Communication Technologies
IGSO	Incline Geosynchronous Orbit
IOV	in-Orbit Validation
IPDL	Idle Period Downlink
LBS	Location Based Services
LTE	Long Term Evolution
MBOC	Multiplexed Binary Offset Carrier
Mcps	Mega Chip Per second
MEO	Medium Earth Orbit
MWW	Mann-Whiteney-Wilcoxon
OS	Open Service
OTDOA	Observed Time Difference of Arrival

PPMC	Pearson Product Moment Linear Correlation Coefficient
PRS	Public Regulated Service
QPSK	Quadrature Phase Shift Keying
RSS	Receiver Signal Strength
RTT	Round Trip Time
SAR	Search and Rescue
SinBOC	Sine Binary Offset Carrier
SOL	Safety of Life Service
SV	Satellite Vehicles
TDOA	Time Difference of Arrival
TOA	Time of Arrival
UE	User Equipment
UWB	Ultra Wide Band
WCDMA	Wideband CDMA
WLAN	Wireless Local Area Network

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Chapter 1

Introduction

The significance of Location Based Services (LBS) is growing day by day. Using the position information of the user in providing various LBS is the primary goal of an LBS system. The continuous advancement of the smartphone technology and user friendliness of the devices have been two big drivers in the growth of LBS. The ever increasing popularity of the LBS applications can be observed from both the user's perspective and the service provider's perspective. The current market research shows that the revenue in this sector is booming rapidly [77]. The primary driver here is the user. User's interests, behavior, needs and perception towards the LBS are the key factors in providing successful location based services.

The underlying technologies to support LBS are multiple and varied. The most known and most reliable outdoor location technology is the one based on Global Navigation Satellite Systems (GNSSs). As of October 2011, the United States NAVSTAR Global Positioning System (GPS) and the Russian GLONASS are fully globally operational global navigation satellite systems. COMPASS-BeiDou 2 satellite navigation system by China and Galileo positioning system by European Union are currently deployed and are estimated to be fully operational within the next 6 to 8 years [5]. Alongside with the existence of diversified satellite positioning systems, other location finding technologies such as cellular-based positioning, WLAN-based positioning and other wireless-signal based positioning (e.g., Bluetooth, DTV/DVB- based positioning) technologies, are currently entering the market in order to complement the areas where GNSS is not enough, such as in indoor environments.

The popularity of LBS is increasing consistently. Currently, there are several companies who are offering various location based services to the consumers. Those services can be categorized non-exhaustively as:

- *personal navigation* (e.g., car navigator) , for example "TomTom" is providing such services [22],
- *tracking* (e.g., lost items, pets) , for example "Polaris Wireless" is providing such services [31],

- *safety and emergency* related services (e.g., weather forecast depending on the location of the user) . For example, “ravemobilesafety” is such company which is providing services already [34],
- *social networking* (e.g., geotagging), e.g., “Foursquare” is providing such feature [38],
- *billing and tolling* (e.g., automatic airport check-in) , e.g., “TOLL COLLECT” is providing location based tolling services in some specific countries already [45],
- *advertising* such as proximity-based notification (e.g., mobile advertising) , e.g., “SKYHOOK” is such kind of company [46],
- *health and sports* related LBS, e.g., “Navizon” [50] and “Endomondo” [48] are providing such services, respectively.
- *on-line location based gaming*, e.g., “GEOCACHING” is a treasure hunt game based on location [51].

User needs, interests and wishes are, obviously, the significant factors while implementing new services or applications on mobile devices. Location based services are some of the key services in mobile devices which provide value-added services to the consumers by using the location information of the mobile. Research and various market studies have been done on LBS future potentials from user’s perspective [55]-[61]. Studies regarding the accuracy of the application, cost and battery consumption to enhancement of social wellbeing due to LBS and privacy concerns have been done, for example in [57]-[59].

In [58] and [59], the user perception towards LBS applications is analyzed with the main focus on cost, privacy concern and importance of various features. The studies from [60] and [61] focused on end-user acceptability and adoption of various ICT services, with LBS included in the studies. Paper based user surveys were conducted in [58] and [59], while in [61], no user surveys were used. Our approach is different from [58] and [59] as follows: no user classification has been attempted in [58] and the volunteer participants in the survey of [58] were all university master-level students while in our current studies we have broader age coverage and a broader educational background, as described later in Chapter 7. The methodology in [58] and [59] is also different from the methodology adopted in this thesis (e.g., electronic surveying tool in here versus paper surveying in [58], [59], no student bonus point incentive and no open-ended questions in here compared to [58], [59], wider population background in here, and generally a more focused approach in this study, aiming at finding the relationship between user classes and their LBS preferences). Also the sample size is larger in this study (118 answers in here, compared to 58 in [59], and 105 in [58]).

Most of the studies so far have been done on closed target user group or specific context of usability of the location based services and applications [58]-[60]. The aim of this thesis is similar to the end-user perception study presented in [58] and [59], but also different in the context of how the survey has been conducted and how the responses of the users were drawn and analyzed. It is also different in the sense that the study addresses user's perception on mobile LBS.

1.1 Thesis Objective & Contributions

The research work of this thesis was financially supported by the Academy of Finland (project 256175) "Cognitive Approaches for Location in Mobile Environments". The research work was carried out in two phases, one phase comprises constructing the survey and another phase consists of the quantitative analysis of the received responses.

The primary objective of this quantitative analysis has been to build a question set according to the requirement, such as categorizing the users into several classes. In doing so, questions were divided in different sets, such as:

1) *general questions related to LBS*, for example: "What are the most important features, from your point of view, of a mobile terminal with location capabilities",
2) *technical questions related to positioning*, for example: "There are currently 5 IOV Galileo satellites on sky" with true/false as answer option,
3) *privacy concern related questions focusing on wireless connectivity*, for example: "How often do you clear your wireless device cache or memory" and
4) *general LBS application usability related questions*, for example: "Assuming all other mobile features equally the same, how much are you willing to pay for a mobile phone with positioning capabilities compared to the basic price x of the same mobile without any positioning".

The objective of these question sets has been to characterize the user needs, behavior and applications in the context of LBS.

The analysis has been done based on the responses at an electronic survey performed among 118 volunteer respondents. The survey was conducted between December 2012 and January 2014. The users are from different fields of study and occupations. Most of the respondents are university graduates and full-time employed, but the age gaps of all the users range from below 20 to above 50. The initial step of the analysis was to define the user classes. There are three user classes defined in the thesis,

1) depending on the technical understanding of the LBS technology: here three levels are defined, level 3 users have the most technical understanding of the technology, level 2 have the moderate and level 1 have the lower.
2) based on the privacy concern of the user. Here also three levels are defined depending on the users' perception towards the privacy concern.

3) based on usability of the LBSs. Here again three levels of usage are employed: heavy usage, moderate usage and low usage of LBS.

After the user classification has been done, the correlation between the user classes is determined. Also LBS usability preferences are compared between different user classes.

The principal focus of our study is to observe the end-user interests towards location based services and applications, while at the same time correlating the user technical level and how they approach or perceive such services in their daily lives. It can also be observed how much of the location based applications users are using and how much they are willing to use the updated features.

The Author’s contributions can be summarized as follows:

1) Defining the survey questions under the supervision and with the input of Associate Prof. Elena-Simona Lohan and Dr. Danai Skournetou,
2) Selecting the best fit-to-purpose software for the electronic survey, after a literature survey of the existing tools,
3) Building the Webropol survey based on the survey questions defined at Contribution (1),
4) Collecting users’ answers during the period December, 2012 – January, 2014,
5) Implementing the software tools for conglomerate data analysis,
6) Defining user classes criteria and thresholds,
7) Analyzing the results in a quantitative manner based on users classes and correlations between classes and using statistical tests.

1.2 Thesis Outline

The remaining of the thesis is as follows:

Chapter 2 includes the overview of the underlying technologies for LBS such as GNSS, cellular-based positioning and WLAN-based positioning.

Chapter 3 presents different Location Based Services offered nowadays. The chapter also presents different companies currently providing such services.

Chapter 4 is the compilation of different research studies regarding the user behavior and preferences in the context of wireless mobile.

Chapter 5 discusses about the online based survey tool used in the research and also points out the advantages of using such tool for a quantitative analysis.

Chapter 6 is about the statistical analysis and existing biases. This chapter explains the different statistical analysis tools and tests used during the analysis. It also discusses about the existing bias present in the survey based research studies.

Chapter 7 comprises the user-based statistical analysis, meaning the analysis of the actual data received during the survey.

Chapter 8 concludes the thesis by pointing out to open directions for the research.

The Appendix shows the Survey Questionnaire with the 38 questions.

Chapter 2

Underlying technologies for LBS

There are various positioning techniques presently in use, e.g., GNSS location, cellular-based positioning, WLAN-based positioning. Some new techniques are still in the research stage, e.g., DTV-based positioning, Bluetooth-based positioning, RFID-based positioning, UWB-based positioning, and other wireless, ultrasound or visible light signals-based positioning techniques.

This chapter discusses the main underlying technologies for LBS. The purpose here is to give a brief overview of the existing main techniques supporting the LBS.

2.1 GNSS Location

The main principle of a satellite navigation system is to determine the location of an electronic receiver by using the time of arrival (TOA) measurements. The position of the receiver is determined accurately (typically within a few meters) by estimating the propagation time of the signal transmitted from the satellites. Various global navigation satellite systems are currently present; those are briefly overviewed in the following sub-sections.

2.1.1 GPS

Today's fully functional Global Positioning System (GPS) is capable of providing accurate, continuous three dimensional position. GPS was actually based on the vision established already during1960s by several U.S. governmental organizations and on the modification done afterwards. Based on this continuous effort of making the positioning system more accurate, the NAVSTAR GPS was formed, which is commonly referred to as only GPS**.** [2]

The Global Positioning System (GPS) provides positioning, navigation, and timing (PNT) services to military, civil and commercial users around the world. GPS is owned by the government of United States. It is fully operational since 1994. Originally, it had 24 satellites; currently, it is functional with 32 satellites. The satellites are divided into six orbits with inclination angle of 55 degrees [1].

As any other GNSS, GPS consists of three segments: Space segment, Control segment and User segment. The space segment represents the constellation of the satellites from where signals are transmitted. Each satellite has a specific signature, also called as a pseudo-random noise (PRN) code. Measurements are calculated and positions are determined at the receiver side from the signal transmitted from the satellites. The control segment is responsible for updating and monitoring the satellites, in order to keep their position status correct. The user segment refers to the actual GPS receiver, which is responsible for processing the received coded signals from the space segment [2]. Nowadays, many mobile devices have incorporated GPS chipsets and may act as a GPS receiver [92][93].

The modulation technique used in GPS is the Direct Sequence Spread Spectrum (DSSS) which is a particular implementation of Code Division Multiple Access (CDMA) techniques. In addition, GPS also uses a Binary Phase Shift Keying (BPSK) modulation scheme. The DSSS signal requires multiplication of the navigation signal with a satellite-specific PRN code. At the receiver side, a multiplication with a reference PRN code, followed by an integrate and dump block enables the precise ranging[2] in satellite navigation. The use of diverse PRN sequences by the transmitter helps to generate multiple distinct signals over a common carrier frequency. The received signals are easily decoded by the receiver as the PRN codes are known [2].

GPS satellites, referred in what follows as Space Vehicles (SVs), transmit signals on three carrier frequencies L1, L2 and L5, with center frequency at 1575.42 MHz, 1227.6 MHz and 1176.45 MHz, respectively. In GPS, two different kinds of codes are used to have distinguishable signal for the receiver, namely C/A (coarse/acquisition) and P (precision). Carrier frequencies are modulated by the above mentioned codes. On the one hand, L1 carrier frequency is modulated by both the C/A and P codes and on the other hand, L2 carrier frequency is only modulated by the P code (which is further modified by Y code and called P(Y) code). The C/A code and P(Y) code has a chip rate of 1.023 MHz and 10.23 MHz respectively. The modern L5 signal carriers (in-phase and quadrature) are typically modulated by two distinct bit trains, one consists of a composite bit train (generated by applying modulo-2 sum on in-phase code), a PRN ranging code and a synchronization sequence, and the other bit train includes a PRN ranging code and a separate synchronization sequence. The PRN ranging codes for the carriers are named as I5-code and Q5 code for in-phase and quadrature, respectively. There are two other civil signals introduced by modern GPS, one is L1C operated in L1 frequency band, and the other is L2C operated in L2 frequency band. One new modulation scheme is introduced by L1C, namely Multiplexed Binary Offset Carrier (MBOC).

2.1.2 Galileo

The successful launch of two fully functional Galileo satellites in October, 2011 and two more in October 2012 made the Galileo system to become a reality [3]. Recently (August 2014), two more Galileo satellites were launched, but they were placed in a wrong orbit and it is yet not clear if they can be used in the future or not. Galileo satellite navigation system shows the prospect of becoming fully operational with 30 satellites by 2019-2020. Galileo satellite navigation system is the joint effort of European Space Agency (ESA) and EU Commission (EC). The fully operational Galileo system will consist of 30 satellites, 27 among them will be operational and three will be active spares in case of any operational satellite fails. The satellites are positioned in three circular Medium Earth Orbit (MEO) planes at an altitude of 23,222 km above the Earth and at an inclination of the orbital planes 56 degrees with reference to the equatorial plane [7][5].

The operating principle of Galileo is the same as for GPS. The main difference stays in the fact that Galileo is an autonomously civilian controlled and monitored system. Galileo navigation system intends to provide various services such as Open Service (OS), Commercial Service (CS), Public Regulated Service (PRS) and Support to Search and Rescue (SAR). The SoL service currently is discontinued and re-profiled [78]. The main objectives of Galileo services are to provide reliable, highly accurate and precise positioning to the user by keeping the integrity of the service at the same time.

The frequency distribution of Galileo system is slightly more diverse than GPS. Galileo transmits signals in four different frequency carriers depending on the service it is providing, namely E1, E6, E5a and E5b (sometimes referred jointly as E5 band). The carrier frequencies for E1, E6 and E5 are 1575.420 MHz, 1278.750 MHz and 1191.795 MHz, respectively. E5a and E5b signals are part of E5 signal in its full bandwidth with carrier frequencies of 1176.450 MHz and 1207.140 MHz, respectively. E1 signal is used in OS and CS with chip rate of 1.023 Mcps and Composite Binary Offset Carrier (CBOC) as modulation scheme. E6 signal is used in CS with chip rate of 5.115 Mcps and Binary Phase Shift Keying (BPSK-5) as modulation scheme. E5 signal is used in OS and CS with chip rate of 10.230 Mcps and Alternative Binary Offset Carrier (AltBOC) as modulation scheme. AltBOC is a modified version of Binary Offset Carrier (BOC) modulation [3].

2.1.3 GLONASS

GLONASS is the Russian fully functional satellite navigation system. The latest constellation of GLONASS consists of 29 satellites among which 24 are fully operational, 4 are spares and 1 in tests phase [8]. The 24 satellites in constellation are positioned in three orbital planes with equally spaced eight satellites in each plane. The orbits are in altitude of 19,100 km over the earth and with an inclination of 64.8 degrees [9].

GLONASS navigation system is intended for both military and civilian use but its development process started on 1976 and initially it was for military purpose only. Later in the process the usage has been set free for the civilians. GLONASS uses FDMA technology, unlike other GNSS systems which use CDMA based methods. It is forecasted that a CDMA component of GLONASS will be available in the near future [79]. The satellites transmit using 25 – channels and the FDMA technique. The bands used here are L1 (ranged from 1602.5625 MHz to 1615.5 MHz) and L2 (ranged from 1240 MHz to 1260 MHz). The modernized GLONASS will use L3 band on carrier frequency 1207.14 MHz to transmit FDMA signal and L5 band with carrier frequency 1176.45 to transmit CDMA signal [79][80]. The spacing between the adjacent frequencies in L1 and L2 are 0.5625 MHz and 0.4375 MHz, respectively. The equation to calculate the center frequency for L1 and L2 carrier is given below [9]:

$$f_0 + n \times f_s \qquad (2.1.3)$$

here,

f_0 for L1 is 1602 MHz and for L2 is 1246 MHz
f_s is the spacing, 0.5625 MHz for L1 and 0.4375 MHz for L2
n is the frequency channel number (0 … 24).

2.1.4 COMPASS/BeiDou-2

BeiDou-2 Navigation Satellite System or also known as COMPASS has been established and is operated autonomously by China. BeiDou-2 satellites are positioned in three orbits namely Geo Stationary Earth Orbit (GEO), Medium Earth Orbit (MEO) and inclined geosynchronous orbit (IGSO) [10]. The full constellation of the BeiDou-2 navigation system is expected to have five GEO satellites and 30 Non-Geo satellites. The non-Geo satellites will consist of 27 MEO and three IGSO satellites [12]. The GEO satellites are positioned at an altitude of 35,786 km and 58.75°E, 80°E, 110.5°E, 140°E and 160°E, respectively. The MEO satellites are positioned at an altitude of 21,500 km over the Earth and at an inclination of 55 degrees. The IGSO satellites are positioned at an altitude of 36,000 km and at an inclination of 55 degrees. The policy report by the BeiDou-2 navigation satellite system shows that the full constellation (approximately 40 satellites with the spare ones) will be achieved in 2018-2020.

BeiDou-2 Navigation Satellite System currently has 16 fully operational satellites. BeiDou-2 satellites uses B1, B2 and B3 signals with carrier frequencies of 1561.098 MHz, 1207.14 MHz and 1268.52 MHz, respectively. The modulation method applied to B1 signal is Quadrature Phase Shift Keying (QPSK-2) and chip rate of 2.046 Mcps. B2 signal

uses QPSK as the modulation scheme and has chip rate of 2.046 Mcps. And B3 signal uses QPSK(10) as the modulation method and has chip rate of 10.23 Mcps [81][82].
In the following Table 2.1, various aspects of GNSS are presented in an aggregate form.

Table 2.1: GNSS in a nutshell [1]-[3],[80]-[82]

	GPS	**Galileo**	**GLONASS**	**COMPASS**
Status	Fully operational since 1994	In process – expected 2018-2020	Fully operational since 2011	In process – expected 2018-2020
Development Started	1960	1999	1976	1980
First Launched Satellite	1978	2011	1982	2007
Last Launched Satellite up to present	2014	2014 (the last launch not fully successful)	2014	2012
Number of satellites (Constellation size)	32	30	29	35
Number of fully functional satellites at present	32	4+2	24	16
Orbital planes	6	3	3	3
Multiple Access Method	CDMA	CDMA	FDMA, possible future CDMA component	CDMA
Modulation Types	BPSK, MBOC	BOC, MBOC	BPSK	QPSK,BPSK, BOC, MBOC

2.2 Cellular Network-Based Positioning

The consistent evolution of Location Based Services applications has raised the interest of the users in various services related to positioning, such as information services (traffic information, city guide), tracking (find a friend, asset tracking), safety and emergency applications (emergency call), medicine and health care, etc. [13]. The above mentioned services can be provided by the satellite based positioning techniques in outdoor environment. But considering different obstructions in the signal path and also the signal availability in indoor situations, where people spend more than 70%-80% of their times, alternative technologies will be useful and worth thinking about. Hence, the cellular network based positioning comes into account. This section briefly describes different techniques used in cellular network based positioning, such as Cell ID, Received Signal Strength, TOA/TDOA, AOA, Round Trip Time, and Assisted-GNSS.

Cell ID (CID) positioning method is one of the basic methods used in cellular network based positioning. The basic principle here is to measure the device position by the knowledge of the serving cell [13]. In the Figure 2.1, the Cell ID method is illustrated, where BS refers to the serving base station and UE is user equipment. The UE's position can be determined by using the latitude-longitude of BS's serving Cell. The accuracy of CID can be enhanced by combining information about the serving sector with the round trip time (RTT) measurement. Based on the RTT and corresponding devices Rx-Tx measurement, the distance between the device and the serving cell can be estimated.

Enhanced Cell ID (E-CID) method is an upgraded technique of CID where additional measurements from UE and Evolved Universal Terrestrial Radio Access Network (E-UTRAN) are used along with the serving cell information. The measurements include UE measurements (e.g., reference signal received power, reference signal received quality and UE time difference between transceiver and receiver) and E-UTRAN measurements (e.g., BS time difference between transceiver and receiver, timing advance and Angle of Arrival) [13].

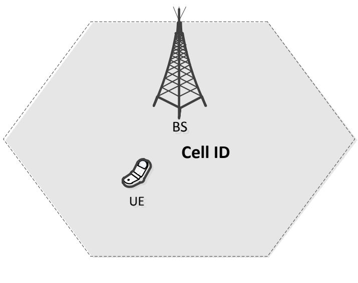

Figure 2.1: Cell ID [84]

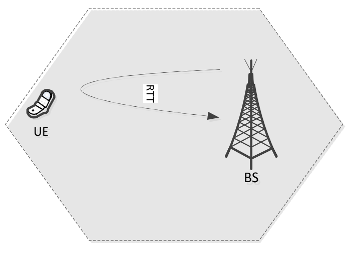

Figure 2.2: Round Trip Time (RTT) [84]

The Round Trip Time (RTT) method determines the position by measuring the time difference between the transmission of the beginning of the downlink dedicated physical channel (DPCH) frame and the reception of the beginning of the corresponding uplink frame [83]. The RTT scenario is presented in the Figure 2.2, where:

$$RTT = T_{UE} - T_{BS} \qquad (2.2)$$

Here,

T_{BS}	=	The time of transmission of the beginning of a downlink DPCH frame from BS to UE
T_{UE}	=	The time of reception of the beginning of the corresponding uplink frame from UE to BS
RTT	=	Round Trip Time

Received Signal Strength (RSS) based method determines the position of the user by using the received signal level. The received signal levels from multiple reference points are considered in order to calculate the position. If the received signals are recognized or calculated in advance, the user position can be found by determining the point of intersection of the three circles. The idea is called trilateration [85]. In the Figure 2.3, the 2-D version of trilateration method is illustrated, where A, B and C are three reference points with co-ordinates (x_a, y_a), (x_b, y_b) and (x_c, y_c) respectively. $X(x, y)$ is the unknown position to measure. $X(x, y)$ can be determined by solving the equations mentioned in 2.3.1, 2.3.2 and 2.3.3

$$(x - x_a)^2 + (y - y_a)^2 = r_a{}^2 \qquad (2.3.1)$$

$$(x - x_b)^2 + (y - y_b)^2 = r_b{}^2 \qquad (2.3.2)$$

$$(x - x_c)^2 + (y - y_c)^2 = r_c{}^2 \qquad (2.3.3)$$

here,

r_a	=	distance between $A(x_a, y_a)$ and $X(x, y)$
r_b	=	distance between $B(x_b, y_b)$ and $X(x, y)$
r_c	=	distance between $C(x_c, y_c)$ and $X(x, y)$

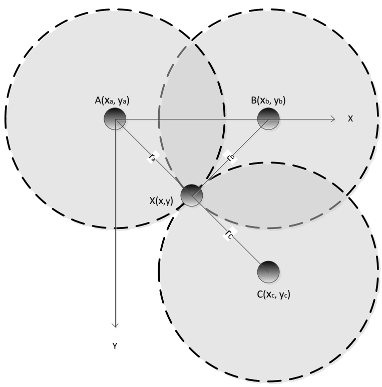

Figure 2.3: Received Signal Strength (RSS) [85]

Time-of-Arrival (TOA) method calculates the position of the user by triangulation principle considering that the signal speed and the propagation time of the signal are known. In the

Figure 2.5 TOA is presented, where UE's position is measured from the intersection of three circles by three base stations: BS1, BS2 and BS3. On the other hand, *Time-Difference-of-Arrival (TDOA)* method measures the position of the user by the differences between the arrivals of the same signal at different sites considering that the sites' position location is known. [84]

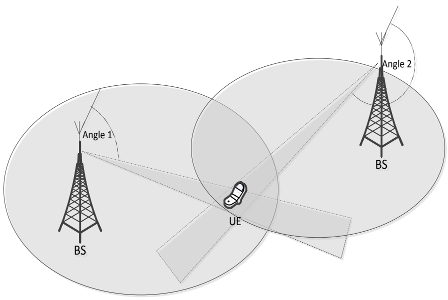

Figure 2.4: Angle-of-arrival (AOA) [84]

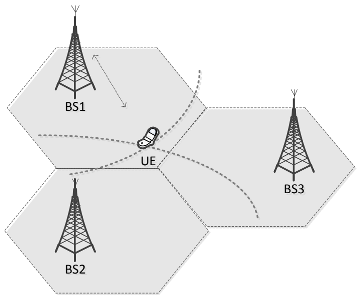

Figure 2.5: Time-of-arrival (TOA) [84]

Angle of Arrival (AOA) technique determines the position of the user by the angle of received signal. The measurement needs minimum two base stations and position measured in BS. The method is shown in Figure 2.4, where angles of received signal corresponding to the two BSs in the plot are calculated as Angle 1 and Angle 2. In AOA method, location errors are proportional to the distance between the BS and UE. [84]

The Observed Time Difference of Arrival (OTDOA) method measures the position of the user by the intersection of two hyperbolas defined by the time difference of arrival signals between two distinct BSs. Each pair of BSs defines one hyperbola; therefore, at least three BSs are needed to determine the position. The method is illustrated in the Figure 2.6.

The Observed Time Difference of Arrival – Idle Period Downlink (OTDOA – IPDL) is a technique to avoid the "hearability" problem. The problem persists in CDMA radio systems where the serving BS cannot hear other BSs on the same frequency. And by providing idle periods in downlink transmission by the BS this inherent problem can be solved. [20].

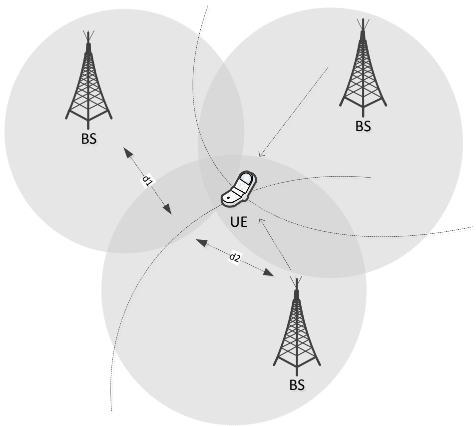

Figure 2.6: Observed time difference of arrival
(OTDOA) [84]

The Assisted-GNSS (A-GNSS) is a method where the Mobile Station (MS) determines the position based on the time of propagation of the signal from the satellite and on the network assistance. MS should be equipped with a GPS receiver in order to fulfill the method. GPS receiver measures the correlation between the received C/A code from the satellite and a locally generated C/A code. The cellular network provides assistance information which helps in the acquisition process. Such assistance information can include the satellite ephemeris, coarse Doppler and code phase estimates, ionopsheric and tropospheric corrections, etc.

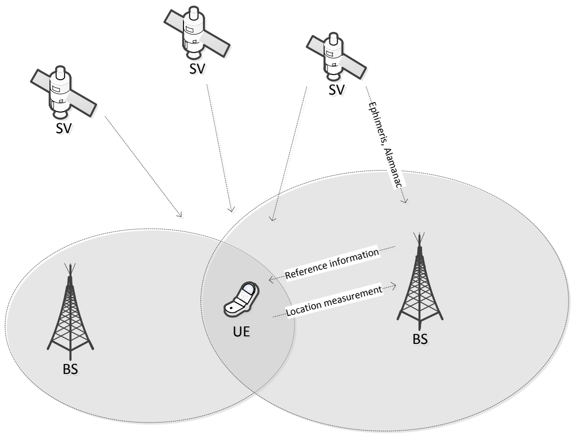

Figure 2.7: Assisted-GNSS [84].

In order to determine the position accurately in A-GNSS, satellite-based information is also required (e.g., time information, satellite clock correction data, ephemeris, almanac, coefficients for the ionospheric delay model). In AGNSS, the cellular network retransmits satellite information as reference model to the receiver in some adverse environments where the information can be lost or obstructed (e.g., indoors). An illustration of the A-GNSS method is presented in the Figure 2.7, in the figure UE determines the position by the help of the satellite information received from the SV and the reference information received from the BS [21][84].

2.3 WLAN Based Location

"Get your position everywhere" is the current concern of Location Based Services where "Availability" and "Accuracy" are the two principle requirements that LBS should fulfill. Satellite and cellular based positioning or the hybrid technologies such as A-GNSS can provide the full support in determining position in outdoor environments. But, there are certain environments or situations where these technologies are not able to be adequate, accurate or available (e.g., indoor or dense – urban areas). WLAN-based positioning promises a complementary solution in such environments. There are currently various methods available for WLAN based positioning. In this section, the most encountered one, namely the Received Signal Strength (RSS) based technique is described. RSS-based approaches can be divided into two main classes: "location fingerprinting model" and "path-loss models".

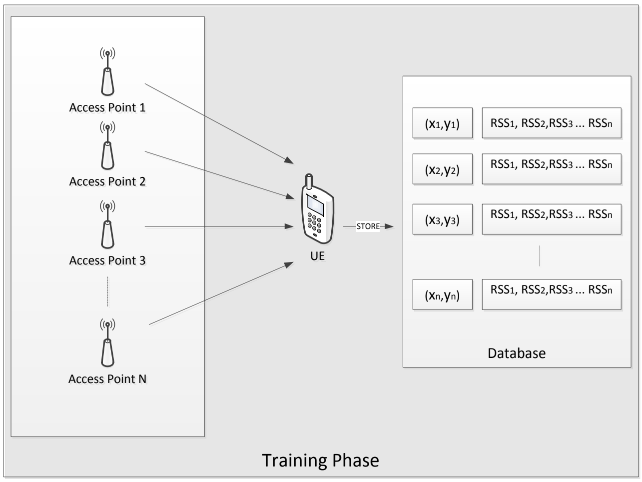

Figure 2.8: Training phase of Fingerprinting approach.[15]

The location fingerprinting approach can be derived in two stages. The first stage is the training stage and the second stage is the position determining stage [15]. The training stage defines the pre-recorded radio signal fingerprints in terms of a database. The construction process of the fingerprint database is presented in the Figure 2.8. The process starts by placing the mobile device to some specific reference point. From that reference point, the signal strength is measured in accordance to various wireless access points and finally the database is completed when all the reference points are traversed.

The second stage is called the position determining stage where the actual tentative position of the UE is determined. The process is presented in the Figure 2.9. In this stage, the mobile device's known RSS measurements are compared with the measurements available in the database, where all RSS's of different reference points of that location were prerecorded. And finally the probable position of the mobile device is determined by applying some searching algorithm on the database, such as nearest neighbor, maximum Gaussian likelihood or rank-based approaches.

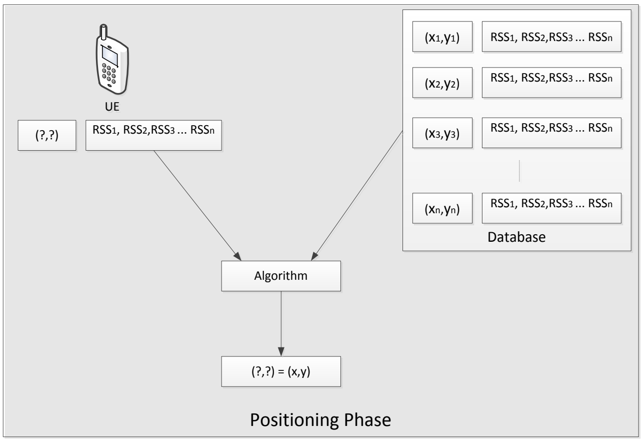

Figure 2.9: Positioning phase of Fingerprinting approach.[15]

Another approach in RSS-based WLAN positioning is the path loss model-based method. A path loss method is similar to fingerprinting approach to some extent as the method uses similar kind of RSS levels matching from various reference points, in order to calculate the position of the mobile device. The approach is different in that it uses a path loss model to determine the RSS of some specific reference point. While determining the path loss model, the channel characteristics such as wall and floor attenuations, may be also considered. Different path loss models have been suggested so far. Various statistical and empirical processing approaches are also presented in different research papers in order to determine the parameters of the model [16]-[19],[86],[91],[94],[95]. Finally the position of the mobile device can be determined by matching the RSS levels measured from different reference points using the path loss model.

An illustrative example of RSS measurements for one Access Point (AP) is shown in Figure 2.10, based on the studies in [86]-[91]. The upper plot shows the power map (i.e., the RSS values) from measured data for one AP inside one university building at the first floor. The middle plot shows the path loss model obtained from the measurements, the bottom plot shows the difference between the measurements (presented in upper plot) and the path loss model (presented in middle plot). Such differences are usually referred as shadowing effect.

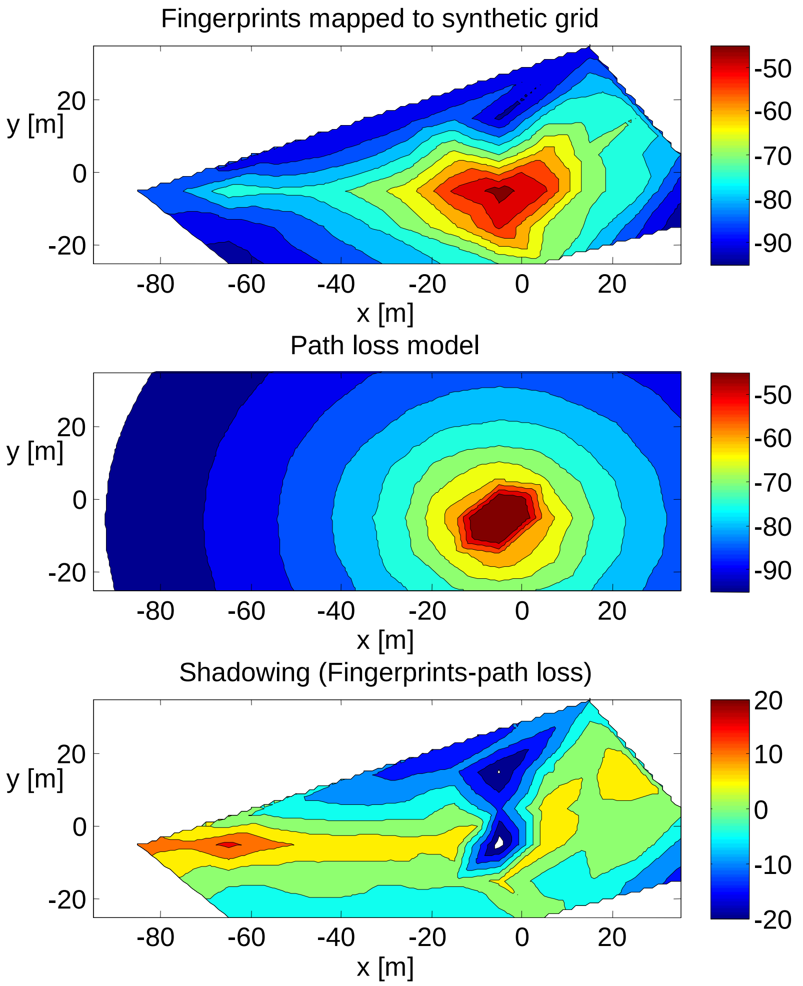

Figure 2.10: Illustration of RSS values and path loss model.

Chapter 3

Location based services

"What is my position on the earth?" is rather a logical question in the current positioning world than a philosophical question. One's position can be easily discovered by the underlying positioning technologies such as GNSS, cellular or other wireless technologies presented in the previous Chapter. The underlying technologies provide the infrastructure and technical support in determining the location, while various location based services bring the actual outcome of the technicalities behind. Nowadays, the variability of the LBS applications is quite high. The diversity of the services may vary from personal navigation and tracking to social networking and advertising, depending on the user and market needs. This chapter provides a brief overview of different LBSs and applications offered nowadays.

3.1 Personal Navigation

Personal Navigation refers to some location-aware services where the user is either stationary or in motion. The services could be related to routing advice, tourist guide or other navigation supports depending on the points of interests. There are several companies which currently provide such routing services. Some examples of companies are presented in the Figure 3.1. TOMTOM along with Tele Atlas are some of the companies which have been providing routing services since 1996 [22]. Tele Atlas is responsible for providing maps to TOMTOM. TeleAtlas was acquired by TOMTOM in 2008. The basic principle of TOMTOM routing service is to give the opportunity to the user to plan their route. The user will give the destination point and the device will calculate the route depending on the position of the user by using a global positioning system. The growing technology of positioning facilitates the location based service provider to give such services at an accurate level.

Figure 3.1: Examples of Personal Navigation LBS service providers [22]-[26],[42],[43].

3.2 Tracking

Finding the specific location of people, devices, pets and vehicles in real time are examples of tracking LBS. Tracking the registered post on-line is one of the most common services that the postal companies are providing nowadays. There are lots of companies in the current world offering such services; the few of those companies are presented in Figure 3.2. LocationLabs is a USA based company, which provides such tracking services (e.g., giving alerts about the movement of a contact of the user) [30]. Polaris Wireless is a very popular company in the field of software based wireless location. Currently, the company has over 45 deployments worldwide and offices in Zug, Switzerland, Bengaluru, India and Dubai, U.A.E and offering two products namely OMNILOCATE and ATLUS [31].

Figure 3.2: Examples of LBS service providers for Tracking applications [27]-[33].

3.3 Safety and Emergency Services

Safety and emergency services are indisputably one of the most significant LBS which are offered to the consumer market in present time. Safety services can be related to weather forecast, any disaster alerts and location-based criminal reports. Nowadays, several companies are providing such services (Figure 3.3). For example: ravemobilesafety is providing various safety alert services, and the company headquarter is in Massachusetts, USA [34]. Emergency call services, such as 911 (US) and 112 (Europe), require that the mobile operators should be responsible for locating the emergency caller's position within certain accuracy and availability limits [36]. There are also some emergency in-vehicle services provided by the car manufacturer, e.g., General Motors (GM)'s OnStar is providing such services [35].

Figure 3.3: Examples of Safety and Emergency service providers [34][35][36].

3.4 Social Networking

The continuous development of smartphone technology and portable smart wireless devices with positioning support facilitates users to access numerous LBS applications anywhere and everywhere. One of the most used applications in smartphone industry is the social networking based applications, e.g., Facebook, Twitter, Google+ and many more (see also Figure 3.4). Location-aware capability of the smartphones made it possible for the users to share their location information with friends and family, also preserving their privacy to some extent. The "check-in" feature is one of the commonly used in different social network based applications.

Figure 3.4: Examples of LBS service providers in Social Networking [37][38][39].

3.5 Information Services

In the territory of LBS, the information services could be any services which provide some type of information based on processing the user location information. The information service can be push-based and pull-based or a mixer of both [62].

- A pull-based service is a direct request-receive service where the user requests some information from the server and server processes the request by using the location information of the user and sends the reply.

- A Push-based service is an indirect service, where the user doesn't request any information, but he/she only shares own location information (preserving the privacy and user consent) and the service provider processes the user's position information and replies depending on the service, e.g., the service provider suggests to the user some nearest restaurant. Advertising LBSs are examples of push-based information services.

There are several companies currently providing such services through application, some of them are presented in the Figure 3.5. The information service is closely related to other information based services such as tracking or safety, emergency services and advertising.

Figure 3.5: Examples of LBS providers in Information services [40][41].

3.6 Billing and Tolling

Location based billing is an LBS which the mobile operators worldwide have been using for determining the call rates. This means, based on the user location, a charge will be deducted (e.g., roaming). Tolling is another kind of LBS that uses the position information of the device (e.g., tolling device – OBU). TOLL COLLECT and VDO are such companies which are providing the service (presented in Figure 3.6). The tolling service is not yet widespread as other billing system due to some standardization issue.

Figure 3.6: Example of LBS providers in Billing and Tolling [44][45].

3.7 Advertising

Location-based advertising is another LBS and marketing industry has been accustomed to it for quite a long time. Advertising depending on the user location can be in form of SMS, MMS or through some mobile application (e.g., social network). Some example companies are presented in the Figure 3.7. SKYHOOK is such company which provides the location-based platform to different LBS applications in advertising. SKYHOOK offers optimized location services by hybrid positioning system that factors Wi-Fi, GPS, cell ID, IP and device sensors [46].

Figure 3.7: Examples of LBS providers in Advertising [46][47].

3.8 Health & Sports

Various applications are currently developed in the sector of sports and health also, such as Endomondo and Nike+ provide services in sports and Navizon in health (presented in the Figure 3.8). Endomondo is a sports tracker which can be used while running or doing any sports to monitor activities. There are many features available in the application e.g., measure the statistics of activities over time, weather information, monitor calories burn, etc. [54]. Endomondo is compatible with most of the operating systems currently present in mobile or some other wireless devices, namely Android, iOS, Windows, Symbian.

Figure 3.8: Examples of LBS providers in Health and Sports [48][49][50].

3.9 Gaming

Location based gaming is the emerging sector in the modern LBS industry. Treasure hunt games like GEOCACHING and GeoSocials (presented in the Figure 3.9) are getting more and more popular nowadays. The main principle of the game is just downloading the application in a positioning enabled device and register for the service. The game progress by searching for a hidden geocache by the help of coordinates set in the GPS-enables device. There are some other forms of the game available with different rules [51].

Figure 3.9: LBS providers in Gaming [51][52].

Chapter 4

User behavior and preferences in wireless mobile

User behavior and preferences are among the significant factors in businesses where the company revenue is highly connected to the user acceptance towards the product. The user behavioral analysis achieves more importance when the business is related to technology. The thriving advancement in smartphone technology has forced service providers to think beyond the boundaries. Hence, the user behavior and preferences analysis in determining and designing the service got an added hype in the research in this sector. This chapter is a compilation of various research studies conducted in the literature, related to user perception-based surveys in the context of wireless mobile, mainly focusing on the LBS applications.

The common focus of the research presented in [55]-[61] is mainly related to the user requirements or perception towards using LBS applications in wireless devices. In most of these research papers, a survey-based approach has been taken into account while gathering the requirements, except few articles [55], [60] and [61] which use different methodologies. But variation in processing the gathered data can be observed in different research papers.

A cognitive process approach has been applied to analyze the user perception in the reference [55]. This means they looked into how much the users' cognitive processes may influence the choice of using LBS. In order to analyze the use of LBS, a heuristic and referencing processes-based framework was proposed in the paper. The investigation was divided into two stages; in the first stage, semi-structured interviews were conducted among 40 users who were German by nationality. The 30 to 45 minutes interview consisted of open-ended questions regarding the LBS usage and the whole process was tape-recorded for future processing. The questions in the first part were designed in a way to facilitate the analysis of the LBS usage in the context of users' cognitive process. In the second stage of the investigation, a diary based method was applied to investigate the daily usage of the LBS usage among 16 people and for a certain period of time. In the process, 16 users were maintaining one diary which contains few questions related to LBS usage but based on context-dependent heuristic processes. In this stage, the motive was to determine the dynamicity of the daily LBS usage of the user considering three heuristic processes namely “availability heuristic”, “representativeness heuristic” and “affect heuristic”. The aim of the research was to suggest one framework (Figure 4.1), which proves that the choice or use of LBS is not only technology driven, but also context or situation dependent.

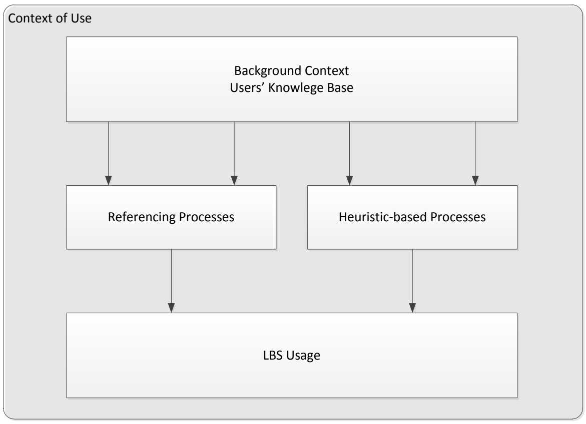

Figure 4.1: Framework proposed in [55].

In [58], the motivation of the paper was solely associated with the end-user perception towards LBS use. The main focus was to conduct a survey in order to evaluate user opinion from diverse contexts of LBS. For example, attention was paid to the most significant features related to positioning-capable wireless device, to future LBS applications acceptability from the cost point of view, to privacy concerns of the user while sharing position information and finally to the evaluation of which LBS will enhance the social wellbeing. The paper-based survey was conducted among 105 BSc and MSc students from two technical universities, namely Tampere University of Technology (TUT) and University "Politechnica" of Bucharest, Romania (UPB). The individuality of this research paper was in how the survey questions were designed, and in the distinct analysis style that has been imposed. The first section of the survey was related to the analysis of the willingness to pay for different LBS applications and desired features. The second section consisted of open-ended questions regarding the situation-dependent future LBS application. The third section referred to the importance of accuracy while proposing some mobility models of certain LBS applications. The fourth section focused on users' willingness to give feedback related to positioning accuracy, while using LBS applications. The fifth section consisted of privacy-related and scenario-based questions. And finally, various questions related to the users' social wellbeing were presented. The result of the survey was measured mainly based on Likert scale and analyzed by correlation between the usage of different applications. In the analysis section, a comparison between two target groups of respondents (TUT and UPB) was made by using three different tests, namely the unpaired test, Mann-Whitney test and the Flingner-Policello test. Finally, one design proposal was presented according to the survey result and analysis. The proposal signifies the interactivity of the users' cognitive processes domain and the designer domain. The proposal is presented here in Figure 4.2.

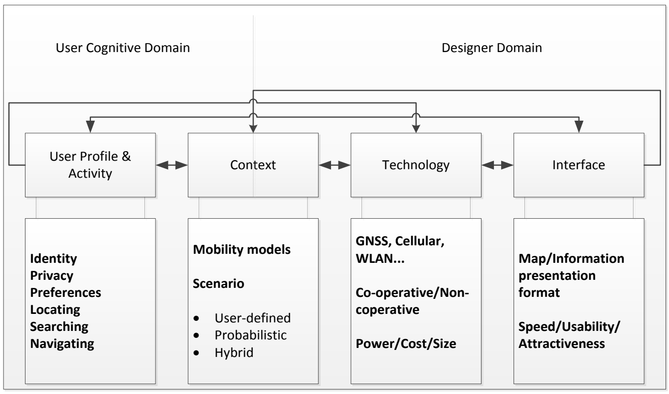

Figure 4.2: Design proposal presented in [58].

The primary objective in [57] was to present a survey-based user acceptance model of Location Based Services. The aim of the research focused on establishing three hypotheses based on users' responses, namely users acceptability towards LBS considering the privacy, distinguishing the adaptability of LBS between different groups that are used as subjects in the survey and finally whether the level of adoption of LBS is proportional to the exposing users' privacy. The introductory section of the research paper presents LBS as the intersection of Geographical information system (GIS), Mobile telecommunication network and Internet. Then the classification of LBS from different perspective presented in the subsequent section which is presented on Figure 4.3. In the concluding part of the paper the result and the analysis method were presented. The survey was focused on two different user groups, one group consists of 181 Croatian students and the second group consists of 180 Croatian general citizens. The result showed that the intended hypotheses can be proven from the gathered data and privacy can be the rejection factor in LBS adoption.

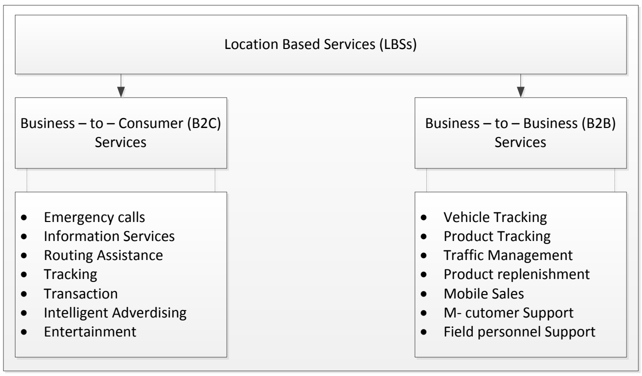

Figure 4.3: Classification of LBS presented in [57].

An end-user perception based study towards various ICT services with LBS included was presented in [60]. The distribution of the research study is different from the typical survey based approach. The aim of the research paper was to propose a model or a framework that establishes a connection between the user adaptability towards different evolving ICT services, on one hand, and the “cost and convenience” in adaptation process, on the other hand. The model was developed based on various literature studies in the domain of ICT services. The model is presented in Figure 4.4. The presented model has three primary components namely the object, the subject and the system. The main addressed point of the model is to show the interdependencies between the components. For example, the subject which refers to the end-user adoption behavior is influenced by the system which comprises society, government or various context of regular life such as culture.

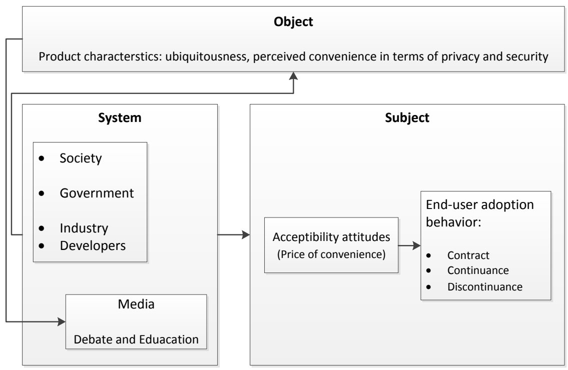

Figure 4.4: Model proposed in [60].

Thus far, the motivation of the preceding research papers was based on the end-user perception. Different methodologies can be observed in various research studies, but the purpose is the same. The input in most of the studies is users’ interest and the output is the designers’ decision making. The objective of the above-mentioned research papers is to facilitate the process of innovation by the help of users’ vision in the context of wireless applications focusing on LBS. The users’ vision includes adaptability of LBS, the variation of choice depending on the situation in the context of LBS, the privacy concerns, the effect of security concerns in adoption of new LBSs and also the usability of LBSs while costs are taken into account. The dynamicity of the users’ preferences can be noticed, regardless of the methodologies used for gathering data. Thus, it can be inferred that the user behavioral analysis is one of the significant tools in the process of designers’ decision making. Therefore, it leads to the motivation of this thesis which proposes an atypical approach of user perception based quantitative studies in the domain of Location Based Services. Our study emphasizes the classification of users from different prospects such as users’ technical knowledge regarding localization, users’ privacy concern and finally users’ LBS usage.

Chapter 5

Online survey tool

The initial step to conduct the survey was to find a method of publishing and collecting the user data, for example either via paper, or via email or with an online survey tool. There are some advantages and disadvantages in all the methods but the most significant advantage of web-based survey over all other is to maintain and organize the survey with ease and to be accessible at any time from everywhere. Some other advantages of the web-based solution adopted in here are listed below:

- It makes the conglomerate analysis easier than in a paper-based survey.
- It provides the user or respondents a certain anonymity (the IP addresses were not stored in performing the survey, and the users had an optional question about their email contact) which is an important requirements while conducting survey.
- It provides an easy and fast way of distribution among respondents.
- It provides flexibility to the respondents for filling up the survey at any suitable time.
- It is easy to design and organize the survey for the creator

The second step was to find an online survey tool with the following desirable features:

- Free for use
- Providing easy analysis of the answers or exporting the results in a format easy to process later on (e.g., Excel, xml or Matlab files)
- Maintaining the security of the survey, meaning that unauthorized access is prohibited
- The tool should be accessible only via a password (password protection)
- The tool should allow the users with access password to answer via 2 types of answers (multiple choice or open)
- The tool should be able to output the answers in an aggregate form
- One user can fill the survey once, multiple access to survey is prohibited
- Each answer should be associated with an user index (in order to be able to analyze correlations between preferences of the same User)
- The anonymity of the users should be preserved and results should be processed in aggregate manner

There were few options taken into account when looking for a web tool to satisfy the above criteria, such as building own web tool or using existing web tool. Finally, the web tool that was decided to be used in the research is Webropol 2.0 [75]. Webropol is an online based survey tool which facilitate user to build survey, publish it among the respondents and generate and analyze reports afterwards. Webropol fulfills all the requirements of the survey and it has various other features that ease the analysis process. The main features of Webropol are presented below:

- *"Compatibility"* - provides add-in feature for Microsoft Word and Outlook, where the creator can transfer the questionnaire directly from Word to Webropol. Outlook add-in facilitates the creator by using the outlook for deploying the survey.

- *"Adaptability"* – provides the feature of jump logic within the survey which helps the user to show relevant question at any given specific scenario.

- *"e-Tests"* – provides immediate way of conducting test and analysis.

- *"Mass reporting"* – provides features which ease the way of analyzing and reporting of the survey is distributed and modular fashion.

- *"360^0 view"* – provides diverse view of questionnaires.

- *"Qualitative Analysis"* – provides text mining which can handle big amount of data.

- *"Periodic report"* – provides the way of analyzing diverse responses from different periods of time. It also supports, designing graphs based on the data.

- *"Diversity in reporting"* – provides various types of application format support while exporting the survey results e.g., word, csv, xml, excel, etc. The diversity in reporting helps the researchers in filtering, producing simulation and analyzing the received data.

- *"Deployment process"* – The deployment process is very easy and user friendly in Webropol. The author of the survey can easily gather all the email addresses by adding them and send the survey link to the respondents just by one click.

- *"Templates and Forms"* – there are 15 survey templates currently available in Webropol. And customized templates can be created depending on the author's needs.

Acquiring license of the tool is another important factor while choosing the web tool. And as the authors of the research study were from TUT and license of the Webropol was free for the TUT staff, the decision of choosing the web tool was straightforward. The most important features of Webropol that have been used while conducting the survey are listed below:

- Diversity in reporting
- Deployment process
- Compatibility
- Adaptability
- Periodic report
- Templates and Forms
- Mass reporting

Chapter 6

Statistical analysis and existing biases

The purpose of a quantitative study refers to the inference of some conclusive statements which satisfies the actual objective of the study, based on some parameters that are easy to be quantified (or measured). Such quantification is typically hard to make when dealing with people's perception and wishes. In order to have a successful analysis and to prove the gathered responses to be significant, the statistical testing is employed in this thesis. This chapter describes briefly some statistical tools used in analysis such as the Likert scale and the measurement correlation parameters. Then later in this chapter, some statistical tests of significance are explained. Finally, the chapter concludes with the description of the self-selection bias present in surveys.

6.1 Likert Scale

The Likert scale has been commonly used in surveys to evaluate the respondents' responses. Likert scale is used in statistical analysis to get the user opinion or attitude towards the questionnaire based on a psychometric scale. Generally, a Likert scale is a five-point bipolar response which ranges from a group of categories. These categories are not definite or there is actually no wrong way of defining them. They can vary depending on the survey requirements. For example, the category could range from least to most likelihood of the context, from "strongly agree" to "strongly disagree", or from "never" to "always". Few of these categories are given in the Table 6.1 [63].

Table 6.1: General category of Likert scale

Scale	**1**	**2**	**3**	**4**	**5**
	Never	Seldom	Sometime	Often	Always
	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

The five-point scale sometimes is extended to seven-point scale according to the need of the survey by adding "very" to the "least" and "most" categories of the scale. Generally, it is recommended to use the scale as wide as possible in order to get the clarity of the analysis. But it always depends on the requirements of the analysis how the scale is customized "condensed" or "expanded". In research analysis, odd scale is preferable to even scale.

Sometimes scales are truncated to an even number e.g., 1 – 4 in place of 1 – 5, which actually forces the choice of the responder by eliminating the “neutral view” option. In order to have a better analysis, it is very important to preserve the respondents’ freedom of choice, hence the neutral option should be considered and the odd scale is preferable [64].

In the Table 6.2 some of the customized scale definitions used in our analysis are provided.

Table 6.2: Customized version of Likert scale

Scale	**1**	**2**	**3**	**4**	**5**
	None	Little	Moderate	Good	Excellent
	Never	Once or few times a year	Monthly	Weekly	Daily
	Not Important	Unimportant	Neutral	Important	Very Important

6.2 Pearson product-moment linear correlation coeffecient (PPMC)

In order to measure the linear correlation between two samples, the Pearson Product-Moment linear Correlation (PPMC) coefficient is used. Generally, PPMC can be also applied to two variables in order to get the linear correlation between them. The equation is presented in terms of determining correlation between two sample distributions. The explanation is given in the context of this thesis, referring to our statistical analysis by correlation of the received responses from various questions presented in the survey [58].

$$PPMC = \frac{\sum_{i=1}^{N}(X_i - \mu_X)(Y_i - \mu_Y)}{\sqrt{\sum_{i=1}^{N}(X_i - \mu_X)^2 \sum_{i=1}^{N}(Y_i - Y_X)^2}} \qquad (6.2)$$

Here,

X	=	sample question one
Y	=	sample question two
i	=	specific user number
N	=	total number of users
X_i	=	Likert value of user i, for question X
Y_i	=	Likert value of user i, for question Y

μ_X = sample mean for question X
μ_Y = sample mean for question Y

The correlation coefficient value ranges from -1 to $+1$, where -1 represents total negative correlation, 0 represents no correlation and $+1$ represents full positive correlation between the samples.

6.3 Statistical tests of significance

A statistical test of significance refers to the process of statistical reasoning from the observed samples. The statistical reasoning facilitates the analyst to estimate the significance of some hypothesis or to infer a conclusion in favor of a claim based on statistical data. The statistical test starts with defining two hypotheses, namely null hypothesis, denoted by H_0 and the alternative hypothesis, denoted by H_a. The null hypothesis is defined as some assumed theory which is not proved yet but set as a base for an argument, and the alternative hypothesis is set based on some claim which the test wants to confirm (or infirm). The other two important parameters in the test process are the significance level α and the $p - value$. The $p - value$ is the probability of a certain value from the test analysis to be obtained at least as extreme as that which was observed. And the significance level is generally set to 0.1, 0.05 or 0.01 which is compared with $p - value$ in a way that if $p - value$ is less than the significance level, the null hypothesis is rejected [71].

There are currently several statistical test methods present in the literature [65] [68], some of them are presented in the following section.

6.3.1 Unpaired t-test

The unpaired t-test is a parametric test based on the assumption of normal distribution of populations. The test equation is presented in (6.3.1) which is used to compare two distinct data samples. The equation may vary depending on the sample type [65][66].

$$\mathrm{t} = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{S_X^2}{N} + \frac{S_Y^2}{M}}} \qquad (6.3.1)$$

Here,

$\bar{X}$ = mean of sample X
$\bar{Y}$ = mean of sample Y

S_X	=	standard deviation of sample X
S_Y	=	standard deviation of sample Y
M	=	sample size of Y
N	=	sample size of X

6.3.2 Mann-Whiteney-Wilcoxon (MWW) test

The MWW test is a non-parametric test where the two distinct populations are compared considering that the populations have equal variances. The test begins with combining the two samples by assigning a rank in such a way where if any sample a from one group is smaller than sample b from other group, the rank 1 is given to that sample. The ranking process can vary according to the context of the test. Finally, the sum of the group ranking is measured and compared with probability table and the $p-value$ is determined. And according to the $p-value$, the rejection of the null hypothesis would be decided[67][68].

$$U = \sum_{j=1}^{N} \sum_{i=1}^{M} \psi(Y_j, X_i) \quad (6.3.2)$$

where,

$$\psi(a,b) = 1 \text{ if } a \leq b \text{ and 0 otherwise.}$$

Here, X and Y are two different observations with M and N number of samples, respectively.

6.3.3 Fligner-Policello (FP) test

FP test is also a non parametric test where two combined group of samples are tested considered that the distribution of the population is not normal and the variances among the samples are not equal. This is the modified or enhanced version of the MWW test. The test begins with two independent random samples from a parent population, e.g., $X_1, X_2, X_3, \ldots, X_M$ and $Y_1, Y_2, Y_3, \ldots, Y_N$. Then in the next step, a ranking process is applied to the combined samples, e.g., rank of the X observation becomes $Q_i, i = 1, 2, \ldots, M$ and the rank of the Y observation becomes $Q_j, j = 1, 2, \ldots, N$. Then, the placement of X_i is defined as $P_i = Q_i - i \ (i = 1, 2, \ldots, M)$, the number of $Y's$ less than X_i. Afterwards, P_i is calculated in terms of the continuous distribution function (cdf). Thus, $P_i = NG_N(X_i)$, where G_N is the continuous distribution function of Y observation. Then, the same process of defining the placement of Y_j is done. The placement of Y_j is $S_j = MF_M(Y_j)$, where $F_M$is the continuous distribution function of X observation. Finally the Fligner-Policello (FP) statistic equation is defined by modifying the Mann-Whitney-Wilcoxon equation to $U = \sum_{i=1}^{M} P_i$ [68][69][70].

$$FP = \frac{N^{\frac{1}{2}}\left(\frac{U}{M \times N} - \frac{1}{2}\right)}{\sigma} \qquad (6.3.3)$$

where,

$$\sigma^2 = \frac{\sum(S_j - \hat{S})^2 + \sum(P_i - \hat{P})^2 + \hat{P} \times \hat{S}}{M^2 \times N}$$

Here,

σ^2	=	variance
P_i	=	placement of X_i
S_j	=	placement of Y_j
$\hat{P}$	=	mean for P
$\hat{S}$	=	mean for S
M	=	Number of samples for observation X
N	=	Number of samples for observation Y
U	=	Mann – Whitney form of statistics, here is modified to $\sum_{i=1}^{M} P_i$

6.4 Self-selection bias in user surveys

Self-selection bias is persistent in quantitative studies based on user surveys. In general, the term self-selection refers to the choice of selection of a quantitative study by the respondents themselves [74]. The result of self-selection affects the analysis by giving biased data. One of the common errors in surveys is the coverage error which is tightly related to the self-selection [72]. The self-selection bias is one of the imperceptible errors that have a biased effect to the result of the analysis. In the survey-based research analysis, it is often observed that the respondents are either chosen depending on the relative field criteria or the survey has been chosen by the respondents due to their interest in the field. Therefore, the process of selection leads to the biased data in the analysis. The self-selection bias may occur due to sampling error [74], that means during the analysis, a sample data is being used, which actually does not represent the whole population. Thus, the process advanced to biased data. Moreover, parts of the answers in our survey were obtained from students enrolled at TUT and getting a bonus point in one course in TUT. Thus, this bonus-point motivation may also introduce certain bias in the survey results. Normally, a large enough sample of population would alleviate the bias.

The availability of internet and the user-friendliness of the technology helps the researchers to organize and gather data with ease, on the other hand brings some issues like self-selection bias [73]. The presence of the issue in technical surveys such as studies related to wireless application is evident. Thus, the self-selection bias must be considered while analyzing the results of the survey or while conducting it.

Chapter 7

User based statistical analysis

The primary objective of the quantitative analysis was to build a question set which will be categorized from three different perspectives. The three considered perspectives were:

1) Categorizing the user classes based on their perceived knowledge in LBS and related underlying technologies.
2) Categorizing the users based on their privacy concerns related to their usage of wireless connectivity and different mobile or location-based application usage.
3) Categorizing the users according to the LBS application usability (meaning their usage and perceived usefulness of LBS).

After the classification criteria are defined and the users have been classified in different user classes, the correlation between the user classes is also investigated in terms of their preferences in LBS. The analysis of the correlation between different user preferences and user classes is presented at the end of this chapter.

Our analysis has been done based on the survey responses of 118 respondents from diverse fields of study and occupations. Most of the respondents are university graduates and full time employed, but the age gaps of all users range from below 20 to above 50 as illustrated in Figure 7.1. The majority of the users were between 21 and 30 years old (about 75% of the users).

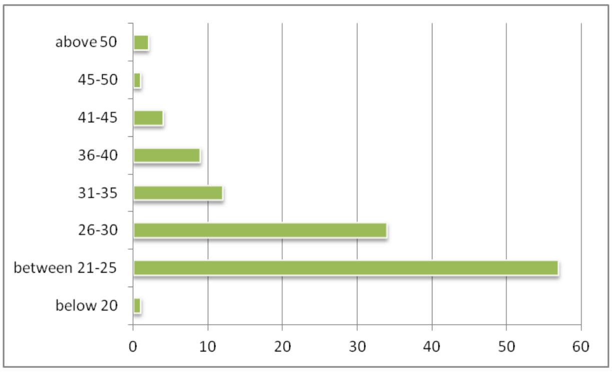

Figure 7.1: Age distribution of the users.

The gender distribution among the participants is 14% females and 86% males. Since most of the respondents were from technical university programs, the big difference in the gender balance could be attributed to the general gender imbalance present in such programs.

The diversity of the respondents comes not only from their educational background and age but also from their country of residence. The respondents are from 17 different countries, as illustrated in Figure 7.2 and the top three countries in the list of participants are those from the three universities involved in data collection, namely Finland, Spain and Romania. One of the participants kept his or her country of residence confidential, which makes the N/A value visible in the chart.

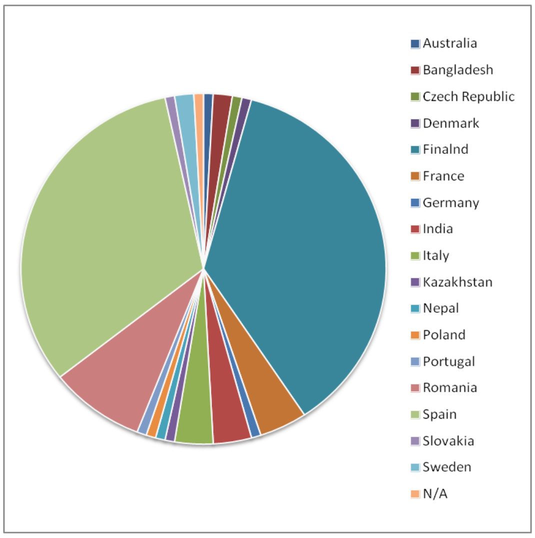

Figure 7.2: Distribution of country of residence.

Figure 7.3 shows the variation in the employment status of the users which consists of the categories: full-time working/employed, part-time working, unemployed and other. Most of the respondents were full-time employed (about 42% of the users).

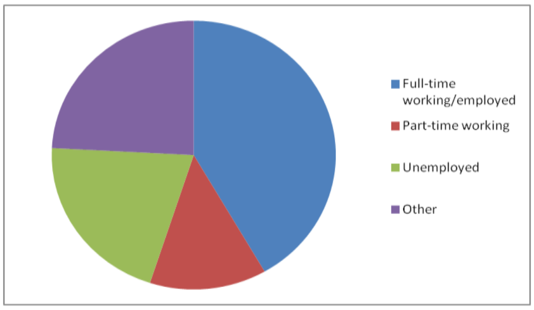

Figure 7.3: Occupation distribution of the users.

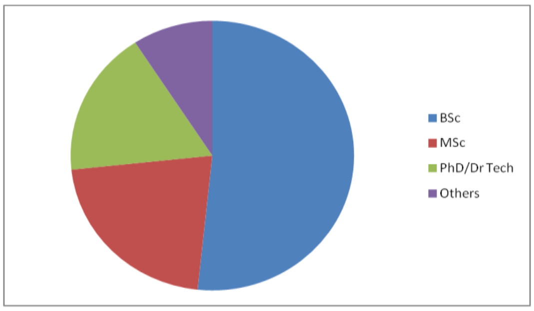

Figure 7.4: Education distribution of the users.

Figure 7.4 shows the distribution of the last completed degree of the respondents where more than 50% of the users have completed Bachelors as their last degree. The ‘others’ option in the figure may signify a non-technical or a degree less than the bachelor degree.

7.1 User Classification 1: Knowledge based

The first classification was done based on the users’ perceived knowledge and on their true knowledge of the technology. In this section users are categorized into three levels:

1) Highly knowledgeable of mobile positioning ICT technology (Connoisseur or Level-3 user),
2) Moderately knowledgeable of the technology (Typical or Level-2 user)
3) Low familiarity of the technology (Non-familiar or Level-1 user).

The knowledge-based classification was done according to some set of background questions. In the first set of questions users were asked to evaluate themselves on a Likert scale from 1 (None) to 5 (Excellent), their level of familiarity with the technical features of the systems used in navigation: GPS, Galileo, GLONASS, COMPASS, EGNOS, WLAN, WCDMA, LTE, UWB, Bluetooth and DTV. The answers to this question were normalized to 1 corresponding to an ‘Excellent’ self-assessed knowledge about all the systems and considered as the perceived knowledge. The second question that has been taken into account for the classification was “The number of wireless devices owned by the users (e.g., mobile phones, GPS, iPod, iPad etc.)” and the options ranged from 1 to more than 5.
The third question in this context was related to the true acquired knowledge of the user based on the question presented in the Table 7.1. The questions mentioned here pertain to the localization technologies specified in the first question in this set. For example: the assertion “There are currently 5 IOV Galileo satellites on sky” had the correct answer of ‘False’ (counted as a ‘hit’), and the other two options were counted as a ‘miss’.

Table 7.1: Question number 10 used in the survey

Q#10: Please fill in the answers you believe to be correct to the following assertions. Use only your current knowledge (no additional Internet search); these assertions are only used to determine your current familiarity with positioning techniques; there is no 'right' or 'wrong' level of familiarity			
	True	False	Don't Know
There are currently 5 IOV Galileo satellites on sky			
Wi-Fi signals can be used for indoor positioning			
Now-a-days typical accuracy of positioning (outdoors) via your mobile phone is at cm level			
GLONASS constellation has 24 active satellites			
Compass system is a fully operational global navigation system as of today (Oct 2012)			
TV signals belong to the so-called Signals of Opportunity and can be used for positioning purposes			
Your position can always be tracked to few tens of meters accuracy by your mobile operator			
In the context of GNSS, GSA stands for the Global mobile Suppliers Association			
If your Bluetooth is 'ON' on your mobile device, your position will be estimated more accurately by any Bluetooth-enabled mobile device			
Code phase measurements can provide much higher accuracy than carrier phase measurements in GNSS			
Multiple Access Scheme used in Galileo is CDMA			
The only multiple access scheme used in Glonass is CDMA			
Ultra wide-band (UWB) signals are very accurate for indoor positioning			
Zigbee consumes more power than Bluetooth connection			
Cooperative positioning means user mobile exchanging location data with nearby mobiles			

The last question in this classification set was related to the usability of some LBS applications by the users. The question is presented in the following Table 7.2.

Table 7.2: Question number 11 used in the survey

Q#11: How often have you used each of the Location Based Services shown below? (Choose the most frequent that applies)				
	At least few times per month	Few times per year	Few times in my life	Never
Getting navigation directions from your car navigator				
Getting navigation directions from your mobile phone				
Using a mobile tracker (e.g. location-enabled clock, bracelet, etc) to track a pet or a member of your family				
Using a sport tracker (e.g. tracking and monitoring your bike routes, etc)				
Using a mobile or web service for real-time urban transportation service tracking (e.g. to see when the next bus is coming to your stop)				
Using a mobile or web service for real-time tracking of your assets/belongings (e.g. Laptop, luggage, car, etc)				
Using location tracking services while gaming online				
Using Location based advertisement in a social network, e.g. facebook				

The equation 7.1 that has been used to calculate the level of familiarity (quantized to 1) of the user is given below, derived empirically by the Author of the thesis:

$$LF = 0.2 * \frac{NOD}{5} + 0.1 * per_{kn} + 0.6 * true_{kn} + 0.1 * used_{LBS} \tag{7.1}$$

Here

NOD	=	Number of wireless devices owned by the users
per_{kn}	=	perceived knowledge of the users
$true_{kn}$	=	true knowledge of the users

$used_{LBS}$ = usability of the LBS applications by the users

The mapping of knowledge-based classification of the users is presented in Table 7.3

Table 7.3: Level of Familiarity mapping

Level-1/ Non-familiar	**Level-2/Typical**	**Level-3/ Connoisseur**
$LF < \frac{1}{3}$	$\frac{1}{3} \leq LF < \frac{2}{3}$	$LF \geq \frac{2}{3}$

The classification percentages according to the knowledge level are given in the Figure 7.5, where most of the users lie in the typical level of familiarity (almost 90% of the users). We also tested whether the correlation of perceived knowledge and the true knowledge is high. The average correlation level over all users was 0.5304, which shows that the mapping was indeed correct (good correlation level). That means that the users perception about their technical knowledge in the field of positioning is highly correlated to the answers the users have given to the questions related to the localization. The correlation of the perceived knowledge and true knowledge for all respondents is presented in the Figure 7.6 with an average correlation coefficient factor of 0.5304. A positive high value shows that indeed the correlation between perceived and true knowledge is strong. Following the correlation, among the 118 users, 55 users were overestimating or overconfident of their knowledge (i.e., perceived knowledge is higher than the true knowledge). This also means that most of the users were either underestimating or estimating correctly their LBS knowledge.

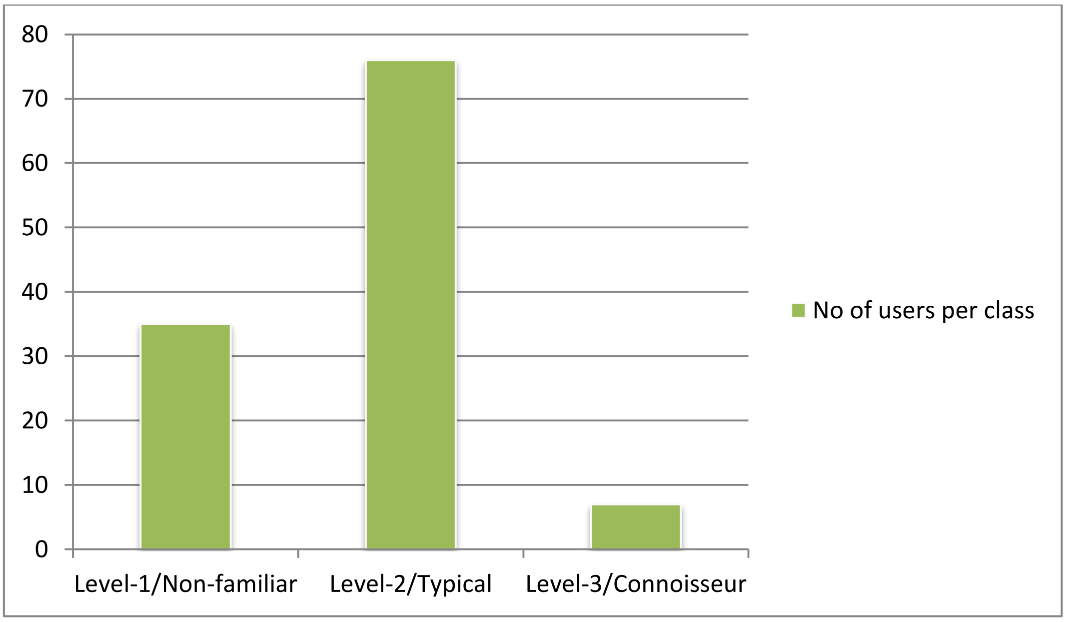

Figure 7.5: Mapping of the level of familiarity.

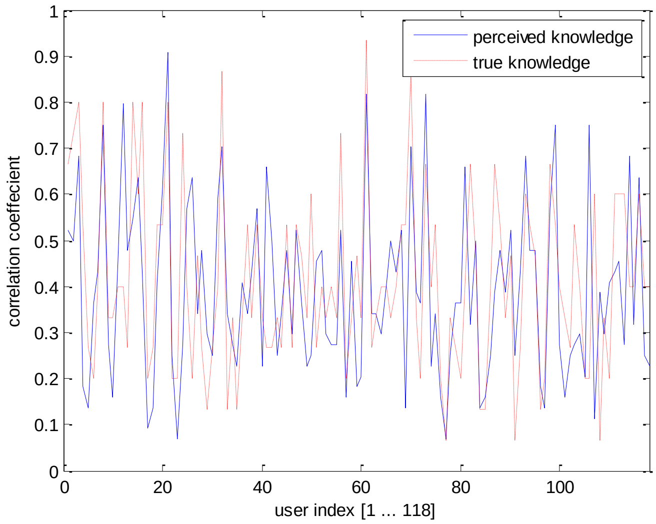

Figure 7.6: Correlation between perceived knowledge and true knowledge.

7.2 User Classification 2: Privacy concern

The second classification was done based on the users' privacy concerns towards using different wireless devices and associated applications on their wireless mobile device(s). In order to determine the user classification, the question set was used from a different perspective. For example we used questions such as:

1) "How often do you clear your wireless device cache or memory?" with choices from "Daily", "Weekly" to "Never",
2) "How often do you log out after logging into an online service or online webpage (e.g., online shopping, online emailing tools, etc)" with choices from "Always" to "Never",
3) "Is the 'Automatic Update' option enabled in your cellular phone?" , with choices "Yes", "No" and "Don't know"
4) "How often do you use unprotected WLAN connection in public places?" with choices from "Always when available" to "Never",
5) "How often in the past have you agreed to let a web or mobile application or service to use your personal data (e.g., your location, contact information, etc.)?" with choices from "Always" to "Never".

All of the questions that have been used in the calculation process are presented in the Table 7.4 to Table 7.9.

Table 7.4: Question number 12 used in the survey

Q_12: How often do you clear your wireless device cache or memory?
- Daily
- Weekly
- Monthly
- Once or few times a year
- Never

Table 7.5: Question number 13 used in the survey

Q_13: Have you ever modified the privacy settings to the highest level other than the default privacy settings provided in the following cases:

	Yes (To Maximum Level)	Yes (To Intermediate Level)	No	N/A (Not own a mobile device)
On your mobile phone				
On your email account				
On your LinkedIn account				
On your Facebook account				

Table 7.6: Question number 14 used in the survey

Q_14: How often do you log out after logging into an online service or online webpage (e.g. online shopping, online emailing tools, etc)
- Always
- Often
- Seldom
- Never

Table 7.7: Question number 15 used in the survey

Q_15: What is the status of the following wireless connections of your wireless phone?

	Always ON	Typically ON	ON only when needed	Don't have/Don't use/Don't Know
Bluetooth				
Zigbee				

WLAN				
WWAN				

Table 7.8: Question number 17 used in the survey

Q_17: How often do you use unprotected WLAN connection in public places?
- Always when available
- Only when travelling and there is no secure free alternative
- Very Seldom
- Never

Table 7.9: Question number 18 used in the survey

Q_18: How often in the past have you agreed to let a web or mobile application or service to use your personal data (e.g. your location, contact information, etc.)?
- Always
- Frequently
- Only when compulsory for completing a operation
- Never

Following the previous classification, the answers to these questions also normalized to 1 and different weights have been used for the different questions. For example, for the Question mentioned in Table 7.5, more weights given to the choice "On your Facebook account" and "On your LinkedIn account" than to the other choices. Also, the maximum weight was given to this question, while it has been used cumulatively with other questions in calculating the classification. Our calculation shows that most of the users are concerned about their privacy; almost 95% of the users reside in the moderate concerned and highly concerned group. More precisely, 64% goes to moderate concerned and 31% goes to highly concerned class (Figure 7.7).

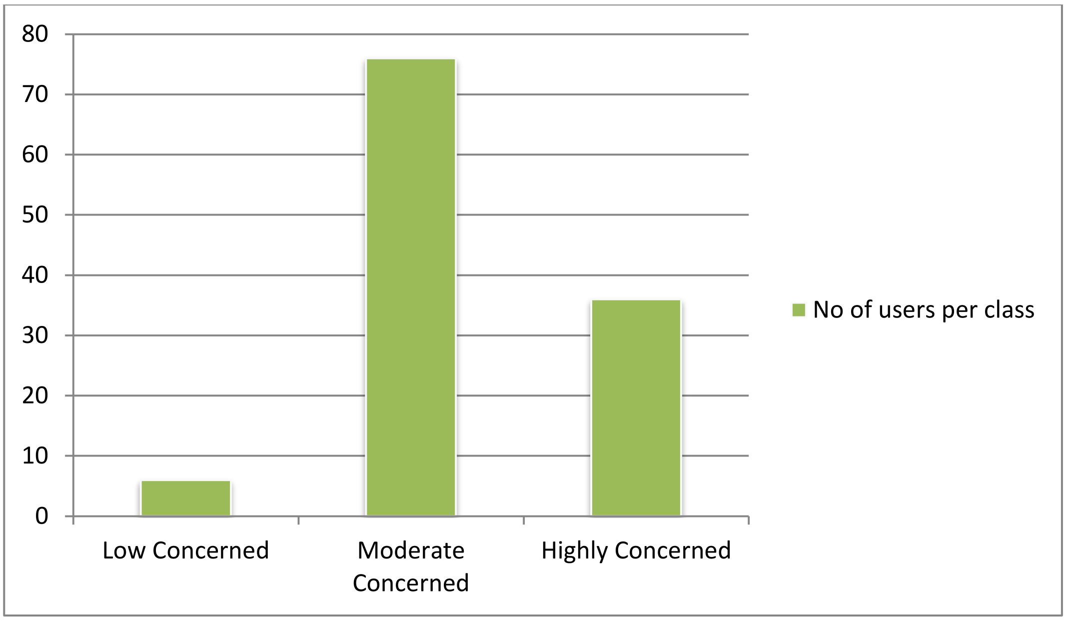

Figure 7.7: Mapping of the level of privacy concern.

Our calculation process for privacy concern-related classification is illustrated in equation (7.2):

$$LP = \left(QF_{12}\left(\frac{wt(Q_{12})}{5}\right) + QF_{13}\left(QF_{13a} \times \frac{wt(Q_{13a})}{3} + QF_{13b} \times \frac{wt(Q_{13b})}{3} + QF_{13c} \times \frac{wt(Q_{13c})}{3} + QF_{13d} \times \frac{wt(Q_{13d})}{3} \right) + QF_{14}\left(wt\,\frac{Q_{14}}{4} \right) + QF_{15}\left(\frac{wt(Q_{15})}{3}\right) + QF_{17}\left(\frac{wt(Q_{17})}{4}\right) + QF_{18}\left(\frac{wt(Q_{18})}{4}\right) \right) \tag{7.2}$$

Here,

LP	=	Level of Privacy Concern
QF_{12}	=	Weighting factor for question 12 (Table 7.4); taken as 0.15
QF_{13}	=	Weighting factor for question 13 (Table 7.5); taken as 0.4
$QF_{13a}, QF_{13b}, QF_{13c}, QF_{13d}$	=	Weighting factor for choices

		of question 13 (Table 7.5); taken as 0.1, 0.1, 0.2, 0.3 respectively
QF_{14}	$=$	Weighting factor for question 14 (Table 7.6); taken as 0.2
QF_{15}	$=$	Weighting factor for question 15 (Table 7.7); taken as 0.05
QF_{17}	$=$	Weighting factor for question 17 (Table 7.8); taken as 0.1
QF_{18}	$=$	Weighting factor for question 18 (Table 7.9); taken as 0.1

Where,

$$QF_{12} + QF_{13} + QF_{15} + QF_{17} + QF_{18} = 1$$

The mapping of privacy concerned based classification of the users is presented in Table 7.10

Table 7.10: Level of Privacy Concern mapping

Level-1/ Low Concern	**Level-2/Moderate Concern**	**Level-3/ High Concern**
$LP < \frac{1}{3}$	$\frac{1}{3} \leq LP < \frac{2}{3}$	$LP \geq \frac{2}{3}$

7.3 User Classification 3: Usability

The third and the final classification has been done based on the usability of the different Location Based Services. The background questions for this classification are given in the following tables Table 7.11, and Table 7.12.

Table 7.11: Question number 7 used in the survey

Q#7: Number of wireless devices (e.g. mobile phone, GPS, iPod, iPad,etc) owned by you
None
1
2
3-5
>5

Table 7.12: Question number 8 used in the survey

Q#8 How much is your average monthly fee for mobile subscriptions (including mobile phone fees, web-based services on your mobile phone if any, fees on your mobile to access online data such as navigation maps)
below 5 EUR/month
between 5 and 10 EUR/month
between 10 and 25 EUR/month
between 25 and 40 EUR/month
between 40 and 60 EUR/month
more than 60 EUR/month

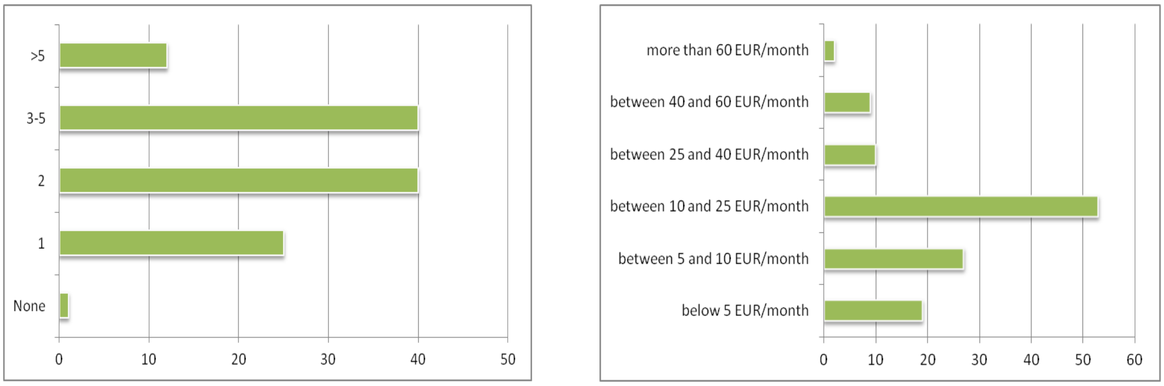

Figure 7.8: Distribution of the results from Question 7 and 8 from Table 7.11 and 7.12, respectively.

The third and the final question is related to the usage of various LBSs already been presented in the knowledge-based classification Table 7.2. The calculation shows that 72% of the users are moderate users of different LBSs (Figure 7.9**)**.

Our calculation process is illustrated in equation (7.2):

$$LU = \left(QF_7 \left(\frac{wt(Q_7)}{4} \right) + QF_8 \left(\frac{wt(Q_8)}{100} \right) + QF_{11}\big(wt(Q_{11})\big) \right) \tag{7.2}$$

Here,

LU	=	Level of Usage
QF_7	=	Weighting factor for question 7 (Table 7.11); taken as 0.15
QF_8	=	Weighting factor for question 8 (Table 7.12); taken as 0.15
QF_{11}	=	Weighting factor for question

11 (Table 7.2); taken as 0.7

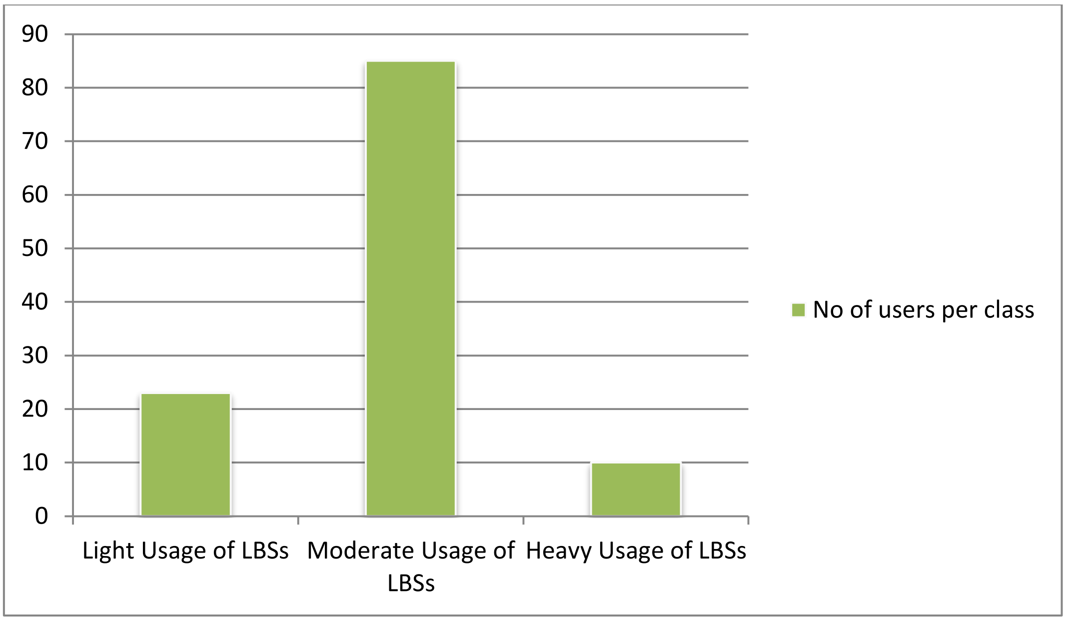

Figure 7.9: Mapping of the level of usage.

The mapping of usage-based classification of the users is presented in the Table 7.13

Table 7.13: Level of Usage mapping

Level-1/ Light Usage of LBS	**Level-2/Moderate Usage of LBS**	**Level-3/ Heavy Usage of LBS**
$LU < \frac{1}{3}$	$\frac{1}{3} \leq LU < \frac{2}{3}$	$LU \geq \frac{2}{3}$

7.4 Correlation between user classes

In this section, the correlations between the user classes are presented. Figure 7.10 shows the correlation between the users of privacy concern-based class and the knowledge-based class. This study shows very low correlation between the two user classes, with a correlation factor of 0.1538. The correlation between usage-based class and the knowledge-based class is presented in Figure 7.11; the correlation is rather low here as well, but better than the previous one with correlation coefficient factor of 0.2414. Figure 7.12 presents the correlation between privacy concern-based class and usage-based class, which also have a low correlation with the correlation coefficient of 0.1597.

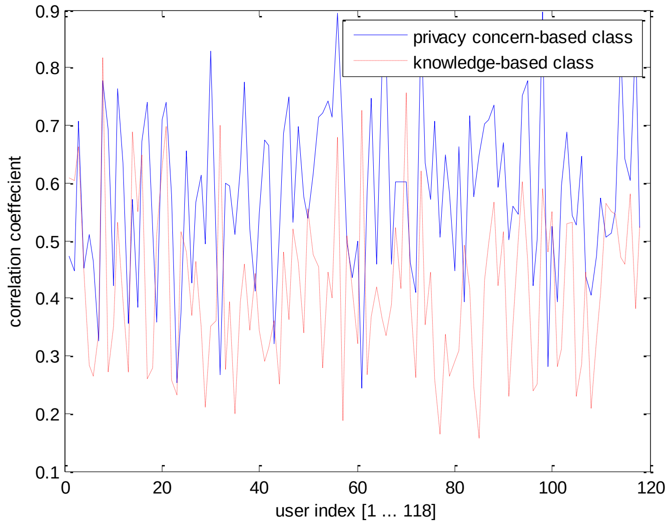

Figure 7.10: Correlation between privacy concern-based class and knowledge-based class.

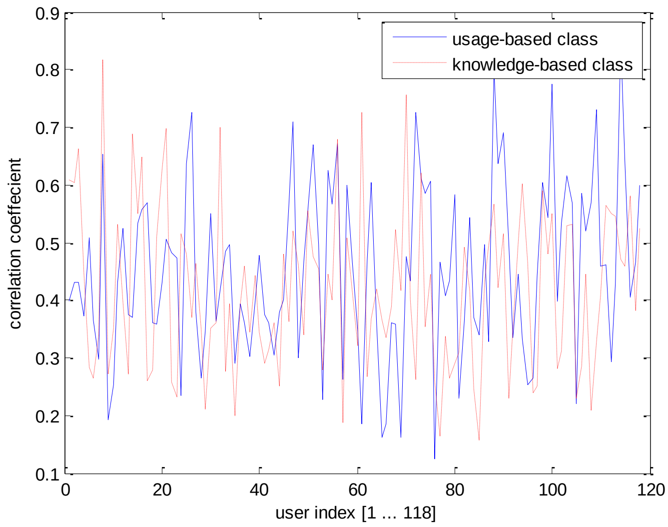

Figure 7.11: Correlation between usage-based class and knowledge-based class.

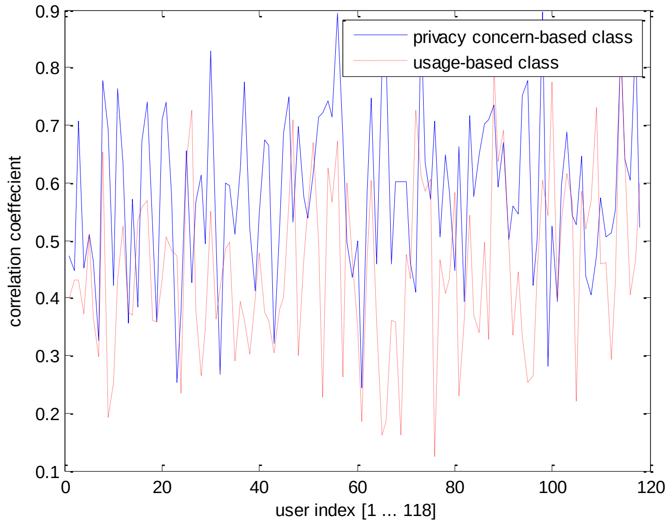

Figure 7.12: Correlation between privacy concern-based class and usage-based class.

7.5 Preferences regarding LBS based on different user classes

Following the classification in the previous section, several user preferences were analyzed per user class and they are presented in this section. Table 7.14 shows how much a user is willing to pay extra for a mobile device with various location capabilities in comparison to a device with no positioning capabilities, such as

1) Basic positioning capability (e.g., cellular-based, accuracy of few hundred meters),
2) GPS-based positioning capability (meter accuracy outdoors, no coverage indoors, long latency at start-up),
3) Assisted-GPS positioning capability(meter accuracy outdoors, limited coverage indoors, fast position computation at start-up),
4) Hybrid high-accuracy positioning (combination of GPS, WLAN, cellular, meter accuracy both indoors and outdoors and 3D positioning).

The answers were mapped to into 1 to 6 scale as follows: 1) less than 10 EUR extra, 2) between 10 and 30 EUR extra, 3) between 30 and 50 EUR extra, 4) between 50 and 80 EUR extra, 5) between 80 and 100 EUR extra, 6) between 100 and 150 EUR extra. The users were asked to choose the interval which is closest to their maximum estimate. In Table 7.14 the mean and the standard deviation per user class are presented for different location capabilities. In general, all the users are willing to pay more for more advanced localization features. Users belonging to the high level of knowledge-based class are less willing to pay and users belonging to the mid and low levels are willing to pay more. The same scenario can be observed in privacy concern-based class, i.e. that the users belonging to the high level of privacy concern-based class are less willing to pay. In usage-based class, the distribution is different from the other two classes, in the sense that the users from the high level of usage-based class are willing to pay more than the mid and low level users. The two most popular features among the users are Hybrid high-accuracy positioning and Assisted-GPS positioning capability.

Table 7.14: User preferences in terms of device price

		Knowledge-based class			Privacy concern-based class			Usage-based class		
		High	Mid	Low	High	Mid	Low	High	Mid	Low
Basic positioning capability	Mean [EUR]	1.00	1.25	1.40	1.08	1.36	1.50	1.40	1.32	1.09
	STD [EUR]	0	0.66	1.17	0.44	0.96	0.55	0.70	0.90	0.51
GPS-based positioning capability	Mean [EUR]	1.14	1.86	1.69	1.50	1.84	2.34	1.80	1.81	1.57
	STD [EUR]	0.38	1.07	1.25	0.85	1.15	1.63	1.03	1.14	1.04
Assisted-GPS positioning capability	Mean [EUR]	1.43	2.32	1.77	1.78	2.22	2.50	2.00	2.19	1.82
	STD [EUR]	0.53	1.38	1.09	1.12	1.33	1.52	0.94	1.33	1.27
Hybrid high-accuracy positioning	Mean [EUR]	1.71	2.74	2.51	2.25	2.75	3.00	3.10	2.64	2.30
	STD [EUR]	0.95	1.62	1.34	1.36	1.54	2.00	1.37	1.53	1.52

Another addressed question was regarding the users' willingness to pay for various location-based services on top of the mobile subscription considering that the services are available to buy. The services were divided into ten LBS classes:

1) emergency alert service that will inform you of any present or forecast disturbances (e.g., floods, crisis, fire, earthquake) in the neighborhood of your location,
2) location-based advertising service (for example, giving you a list with all nearby shops having a desired item and a list of their prices/specifications),
3) public transport routing service (for example, showing you several routes between point A and point B via public transport, what are the fees to get from point A and point B, which is the fastest route and what is the status of the traffic: fluent/congested),

4) pollution-level indicator service (for example, showing what is the air and water quality of the town/district you are in and which are the health risks associated with that quality level),
5) personalized health-advice service: for example, based on your medical history and physical activity levels, you will get daily recommendations about the healthy level of exercise/physical activity to achieve and indications about nearby places where you can perform physical activity (gyms, swimming pools, etc.)
6) social networking service: for example, based on your pre-defined hobbies and interests, you will get (on demand) sms alerts with coordinates of other people with similar hobbies/interests that have subscribed to this service,
7) LBS about the location of your children, close family & friends, assuming they gave the consent to be located/tracked by you,
8) checking automatically or automatic payment for a museum, train, theater show, etc, based on your mobile device with location capabilities (this would decrease the queues and waiting times),
9) automatic geo-tagging of photos taken with mobile device,
10) Facebook- 'check-in' application (to be able to 'check-in' at the location you are).

The answers were quantized on levels from 0 to 5 according to the maximum monthly fee the users were willing to pay for each application, as follows: 0) 0 EUR, 1) between 0 and 1 EUR, 2) between 1 and 2 EUR, 3) between 2 and 5 EUR, 4) between 5 and 10 EUR, 5) between 10 and 20 EUR. Table 7.15 presents the mean and standard deviation per user class for different LBS application classes. The result shows that the popular applications among all the user classes were as follows:

i) the public transport routing service,
ii) the personalized health-advice service,
iii) the family tracking service,
iv) the automatic payment service.

In addition to the above mentioned applications, emergency alert service and pollution level indicator service are also popular among the high level knowledge-based users. Variations among different user classes are also present here while choosing different applications. Users from the high level of knowledge-based class are more willing to pay for the popular applications mentioned earlier. For the privacy concern-based class, low privacy concerned users are more willing to pay (considering the popular applications). In the usage-based class, users belonging to the high level are more willing to pay. The least popular applications among the users are:

i) Facebook ‘check –in’ application,
ii) Automatic geo tagging of photos,
iii) LBS-based advertising service, and
iv) Social networking service.

Table 7.15: User preferences in terms of monthly fee per LBS

		Knowledge-based class			Privacy concern-based class			Usage-based class		
		High	Mid	Low	High	Mid	Low	High	Mid	Low
Emergency alert service	Mean [EUR]	1.29	1.00	0.85	0.75	1.09	0.83	1.70	0.87	1.04
	STD [EUR]	0.48	1.08	1.11	0.93	1.13	0.75	1.64	0.96	1.06
LBS-based advertising service	Mean [EUR]	0.29	0.79	0.91	0.67	0.86	0.83	1.20	0.75	0.78
	STD [EUR]	0.48	1.02	0.98	0.89	1.01	1.32	1.03	0.96	1.08
Public transport routing service	Mean [EUR]	1.28	1.57	1.31	1.36	1.46	2.33	2.30	1.38	1.43
	STD [EUR]	0.75	1.13	0.96	0.99	1.10	0.82	0.94	1.05	1.03
Pollution-level indicator service	Mean [EUR]	1.00	0.71	0.65	0.83	0.67	0.50	1.80	0.61	0.61
	STD [EUR]	1.41	0.99	1.13	1.13	1.05	0.55	1.68	0.94	0.89
Personalized health-advice service	Mean [EUR]	0.57	1.14	1.17	1.02	1.17	1.00	1.70	1.15	0.74
	STD [EUR]	1.13	1.18	1.32	0.99	1.29	1.67	1.95	1.14	1.01
Social networking service	Mean [EUR]	0.43	0.79	0.77	0.67	0.82	0.67	1.40	0.77	0.43
	STD [EUR]	0.54	1.07	1.00	0.86	1.12	0.82	1.07	1.06	0.73
Family tracking	Mean [EUR]	1.57	1.14	1.25	1.11	1.22	1.50	2.20	1.20	0.78
	STD [EUR]	1.27	1.13	1.29	1.14	1.23	1.04	1.22	1.18	0.95
Automatic payment	Mean [EUR]	1.57	1.35	0.88	1.06	1.28	1.67	2.10	1.22	0.87
	STD [EUR]	0.78	1.08	1.07	0.98	1.12	1.21	0.99	1.03	1.14
Automatic geo-tagging	Mean [EUR]	0.57	0.59	0.66	0.42	0.70	0.67	1.30	0.61	0.30
	STD	0.79	0.85	0.91	0.69	0.91	1.03	1.33	0.80	0.63

	[EUR]									
Facebook- 'check-in' application	Mean [EUR]	0.14	0.54	0.60	0.55	0.57	0	1.20	0.57	0.08
	STD [EUR]	0.38	0.99	0.91	0.97	0.97	0	1.31	0.96	0.28

Table 7.16: How much users are willing to pay if the services are offered in bundle

		Knowledge-based class			Privacy concern-based class			Usage-based class		
		High	Mid	Low	High	Mid	Low	High	Mid	Low
Overall average monthly fee for LBS package	Mean [EUR]	6.71	10.68	8.83	9.25	10.39	7.50	10.40	8.20	15.96
	STD [EUR]	3.25	23.88	9.32	10.01	23.72	5.32	15.01	8.74	40.67

Table 7.16 shows also how much the users would be willing to pay per month for a bundle of LBS services (e.g., when all the above mentioned LBS would be offered jointly). The values in the Table 7.16 are given in EUR and they match with the previous observation that the high level users of knowledge-based class and high level of privacy concerned users are less willing to pay. Surprisingly, the users belonging to light usage of LBSs are more willing to pay when the applications are offered in bundle.

The analysis so far has been done based on several user preferences related to costs. Table 7.17 shows also the desired level of detail for the display of the location on the mobile screen, assuming that such levels were technically possible. Three scenarios were considered as case studies: outdoor rural, outdoor urban and indoors, and the desired level of accuracy was quantized from level 0 (10 m accuracy) to level 3 (1 cm accuracy). Level 1 corresponds to 1 m accuracy and level 2 corresponds to 10 cm accuracy. Realistic choices have been made by the users regardless of the user classes they belong. For outdoor cases, suburban and indoors sub-meter accuracy is desired by all the user classes (most mean values are around level 2, that means 10 cm accuracy).

Table 7.17: Desired level of detail in terms of accuracy

		Knowledge-based class			Privacy concern-based class			Usage-based class		
		High	Mid	Low	High	Mid	Low	High	Mid	Low
Outdoors, rural	Mean [Likert	2.00	1.69	1.63	1.75	1.66	1.83	1.80	1.72	1.57

	index]									
	STD [Likert index]	1.00	0.69	0.84	0.81	0.74	0.75	0.92	0.76	0.66
Outdoors, urban	Mean [Likert index]	2.29	2.19	2.03	2.25	2.09	2.33	2.40	2.14	2.08
	STD [Likert index]	0.76	0.63	0.66	0.81	0.57	0.52	0.84	0.62	0.67
Indoors	Mean [Likert index]	2.28	2.45	2.34	2.58	2.34	2.16	2.80	2.32	2.57
	STD [Likert index]	0.75	0.95	0.97	1.02	0.88	1.17	0.92	0.91	1.04

Table 7.18 illustrates the distribution of the appreciated features in a mobile device with location capabilities among the users. The users' choices were:

1) Very high accuracy of the location position (e.g., average errors less than 1 m) indoors,
2) Very high accuracy of the location position (e.g., average errors less than 1 m) outdoors, Moderate accuracy of the location position (e.g., average errors less than few tens of m) indoors,
3) Moderate accuracy of the location position (e.g., average errors less than few tens of m) outdoors,
4) Very high availability of the position estimate (e.g., to be able to receive your location estimate in more than 98% cases) indoors,
5) Very high availability of the position estimate (e.g., to be able to receive your location estimate in more than 98% cases) outdoors,
6) Moderate availability of the position estimate (e.g., in more than 70% cases) indoors,
7) Moderate availability of the position estimate (e.g., in more than 70% cases) outdoors,
8) Short delays (e.g. time to start a certain location-based application on your mobile),
9) User friendliness (e.g., ease of use of a certain location-based application on your mobile device),
10) Small amount of manual settings (e.g., adjustments in the application settings according to location to be done as much as possible automatically),

11) Personalized features (e.g., to be able to set manually certain user profiles, such as pedestrian/car; office/travel and certain user parameters, such as maximum speed, user height for step size adjustments in positioning, typical placement of phone: pocket/bag, etc.).

Table 7.18: Users' appreciation towards different features of positioning

		Knowledge-based class			Privacy concern-based class			Usage-based class		
		High	Mid	Low	High	Mid	Low	High	Mid	Low
Very high accuracy of the location position(indoors)	Mean [Likert index]	3.29	2.58	2.11	2.75	2.29	3.34	3.00	2.41	2.52
	STD [Likert index]	1.26	1.37	1.30	1.59	1.21	1.36	1.15	1.42	1.20
Very high accuracy of the location position (outdoors)	Mean [Likert index]	3.57	3.33	3.09	3.42	3.25	2.67	3.20	3.38	2.91
	STD [Likert index]	0.98	1.23	1.42	1.16	1.28	1.86	1.03	1.26	1.38
Moderate accuracy of the location position (indoors)	Mean [Likert index]	2.86	2.87	1.97	2.58	2.64	2.17	3.20	2.52	2.65
	STD [Likert index]	1.68	1.23	1.34	1.52	1.25	1.47	1.14	1.33	1.43
Moderate accuracy of the location position (outdoors)	Mean [Likert index]	3.71	3.30	2.57	2.78	3.26	3.17	3.50	2.98	3.43
	STD [Likert index]	1.89	1.43	1.54	1.67	1.41	1.94	1.43	1.51	1.59
Very high availability of the position estimate (indoors)	Mean [Likert index]	3.29	2.92	2.54	3.03	2.68	3.50	2.50	2.76	3.22
	STD [Likert index]	1.25	1.38	1.52	1.54	1.35	1.52	1.84	1.42	1.20

Very high availability of the position estimate (outdoors)	Mean [Likert index]	4.14	3.89	3.08	3.72	3.61	4.17	3.50	3.59	4.04
	STD [Likert index]	1.21	1.15	1.46	1.26	1.27	2.04	1.43	1.30	1.22
Moderate availability of the position estimate (indoors)	Mean [Likert index]	3.28	2.51	2.11	2.50	2.35	3.17	2.80	2.29	2.83
	STD [Likert index]	1.11	1.31	1.18	1.57	1.13	1.17	0.79	1.29	1.37
Moderate availability of the position estimate (outdoors)	Mean [Likert index]	3.71	3.20	2.43	2.78	3.12	2.83	3.60	2.82	3.39
	STD [Likert index]	1.49	1.55	1.56	1.71	1.53	1.60	1.07	1.63	1.53
Short delays	Mean [Likert index]	3.43	3.66	2.91	3.39	3.42	3.67	3.80	3.27	3.83
	STD [Likert index]	0.97	1.35	1.74	1.52	1.53	0.82	1.13	1.61	0.98
User friendliness	Mean [Likert index]	2.71	3.51	3.71	3.22	3.65	3.84	3.60	3.42	3.87
	STD [Likert index]	0.95	1.35	1.43	1.42	1.36	0.75	1.35	1.42	1.14
Small amount of manual settings	Mean [Likert index]	2.29	2.86	2.88	2.83	2.89	2.00	2.60	2.80	3.04
	STD [Likert index]	1.11	1.37	1.25	1.32	1.27	1.89	1.35	1.36	1.18
Personalized features	Mean [Likert index]	2.86	3.13	3.11	3.25	3.09	2.50	2.70	3.11	3.26

	STD [Likert index]	0.90	1.45	1.36	1.44	1.35	1.64	1.16	1.47	1.14

The top appreciated features among all the users were:

- very high accuracy (outdoors),
- very high availability (outdoors),
- short delays,
- user friendliness and
- personalized features.

High level users in knowledge-based class want moderate accuracy and availability indoors, while high and moderate privacy concerned users want personalized features. High usage class users also show the same as the high knowledge-based class users in case of accurate and available position in indoors.

7.6 Class similarity analysis

This section emphasizes on the similarity or differences between different user classes by applying several statistical tests of significance. There are various statistical tests available to compare populations of unequal sizes, as described in Chapter 6. Here, three of the tests of significance are applied on the findings, namely: FP, MWW and Unpaired t-test. The test specifications are explained in Chapter 6

The above mentioned three tests use two hypotheses to compare the distribution, denoted by H_0 $(null\ hypothesis)$ and H_a $(alternative\ hypothesis)$.

here,

H_0 : two user classes have similar preferences
H_a : the difference between the groups is statistically significant

And the significance level used here is denoted by α.

The use cases here are the two user classes from different category. And in all the tests, four different user preference categories are used in the context of LBS. In the first category, “how much users are willing to pay for a device with diverse positioning capabilities attached considering other features are same in the device” is used. In the second category, “How much level of details users want in different scenarios” is used. The third category contains “How much users want to pay for various applications related to LBS”. And finally "How much as a maximum users want to pay if all applications mentioned in the last category are provided as a bundle" is used.

The first use case is presented in Table 7.19, preference dissimilarity between high level users of knowledge-based class and usage-based class is shown. The three tests compute the $\boldsymbol{p-value}$ at a certain level $\boldsymbol{\alpha = 0.1}$, where large $\boldsymbol{p-value}$ from the threshold indicates that the difference between the preferences is very little, on the other hand, a small $\boldsymbol{p-value}$ denotes that the difference is high between the classes in terms of preference. From the test result it can be observed that in the most cases there is no significant dissimilarity between the user classes, which is expected.

Table 7.19: Statistical analysis (FP, MWW and Unpaired t-test) among user classes

		FP, $\boldsymbol{p-value}$ ($\boldsymbol{\alpha = 0.1}$)	MWW,$\boldsymbol{p-value}$ ($\boldsymbol{\alpha = 0.1}$)	Unpaired t-test, $\boldsymbol{p-value}$ ($\boldsymbol{\alpha = 0.1}$)	$\boldsymbol{H_0}$ rejected (i.e., significantly dissimilar preferences)
Willing to pay Device price for	basic cellular-only location capability	0.8598	0.1196	0.1547	NO
	GPS based positioning capability	0.9146	0.1126	0.1311	NO
	Assisted GPS positioning capability	0.8801	0.1813	0.1702	NO
	Hybrid high-accuracy positioning capability	0.9809	0.0384	0.0359	YES
Level of detail	Outdoors rural	0.3719	0.6288	0.6760	NO
	Outdoors urban	0.6960	0.7459	0.7784	NO
	Indoors	0.8801	0.2117	0.2424	NO
	emergency	0.5566	0.9131	0.5290	NO
	advertise	0.9723	0.0513	0.0470	YES
	transport	0.9785	0.0375	0.0330	YES
	pollution level indicator	0.8852	0.2387	0.3215	NO
	health advice	0.8651	0.2184	0.1903	NO

Willing pay for services	social networking	0.9723	0.0482	0.0444	YES
	family tracking	0.8651	0.3343	0.3225	NO
	automatic payment	0.8651	0.2422	0.2604	NO
	automatic geo-tagging	0.8651	0.2288	0.2178	NO
	automatic Facebook check-in	0.9649	0.0474	0.0585	YES
All the services	Max Payment	0.3698	0.7630	0.5359	NO

Table 7.20: Statistical analysis (FP, MWW and Unpaired t-test) among user classes

		FP, $\boldsymbol{p-value}$ $(\boldsymbol{\alpha = 0.1})$	MWW,$\boldsymbol{p-value}$ $(\boldsymbol{\alpha = 0.1})$	Unpaired t-test, $\boldsymbol{p-value}$ $(\boldsymbol{\alpha = 0.1})$	$\boldsymbol{H_0}$ rejected (i.e., significantly dissimilar preferences)
Willing to pay Device price for	basic cellular-only location capability	0.4616	0.4676	0.5910	NO
	GPS based positioning capability	0.3118	0.4891	0.8035	NO
	Assisted GPS positioning capability	0.2700	0.5595	0.5515	NO
	Hybrid high-accuracy positioning capability	0.3495	0.7321	0.6835	NO
Level of detail	Outdoors rural	0.4791	0.6044	0.8983	NO
	Outdoors urban	0.1807	0.4031	0.4495	NO
	Indoors	0.1337	0.2662	0.2899	NO
	emergency	0.2746	0.3428	0.4230	NO
	advertise	0.4542	0.3847	0.8158	NO
	transport	0.1782	0.3036	0.3062	NO
	pollution level	0.2566	0.2348	0.5174	NO

	indicator				
Willing pay for services	health advice	0.4504	0.6026	0.9645	NO
	social networking	0.4963	0.3554	0.9386	NO
	family tracking	0.4047	0.5545	0.7638	NO
	automatic payment	0.2356	0.3760	0.4291	NO
	automatic geo-tagging	0.3640	0.3527	0.8804	NO
	automatic Facebook check-in	0.3221	0.2201	0.8119	NO
All the services	Max Payment	0.4294	0.9491	0.3723	NO

The second use case for test is presented in Table 7.20, which shows the preference dissimilarity between mid-level users of knowledge-based and usage-based class. The test result is expected here also that null hypothesis is not rejected, that means there is no significant dissimilarity between the two user groups. From the table of test results, it can be observed that the $\boldsymbol{p-value}$ is significantly higher than the threshold, hence the conclusion that can be derived is that there is no significant difference between preferences of two same level user groups even if they are chosen from a different user classification category.

In Table 7.21, $p-value$ for FP test is compared for three different categories of groups. In the first pair, Knowledge-based high level users are compared with low level users from same class. From the results, it can be observed that significant dissimilarity is present in 50% of the preference choices (which is expected). But that means, that for some choices the difference between the high level knowledge-based users and low level knowledge-based users is not significant or similar to some extent. In the second pair, Usage-based high level users are compared with low level users of the same class in terms of preferences. Here also equally distributed results can be observed, where the level of statistical difference varies in preferences. And finally in the third pair, Knowledge-based low level users are compared with Usage high level users. The result of this pair is also as expected, i.e. in most of the cases, significant dissimilarity can be observed between the groups.

Table 7.21: Statistical analysis (FP test) among user classes

		Knowledge-based (high-low) FP, $(p-value/H_0\,rejected)$	Usage-based (high-low) FP, $(p-value/H_0\,rejected)$	Knowledge-based (low) vs. Usage-based (high) FP, $(p-value/H_0\,rejected)$
Willing to pay Device price for	basic cellular-only location capability	0.0997/YES	0.1257/NO	0.2553/NO
	GPS based positioning capability	0.0810/YES	0.2424/NO	0.2559/NO
	Assisted GPS positioning capability	0.2073/NO	0.2610/NO	0.2181/NO
	Hybrid high-accuracy positioning capability	0.0440/YES	0.0653/YES	0.0946/YES
Level of detail	Outdoors rural	0.1229/NO	0.2709/NO	0.2519/NO
	Outdoors urban	0.2031/NO	0.1740/YES	0.0937/YES
	Indoors	0.4070/NO	0.2662/NO	0.0858/YES
Willing pay for services	emergency	0.0026/YES	0.1448/NO	0.0344/NO
	advertise	0.0178/YES	0.1051/NO	0.2054/NO
	transport	0.4616/NO	0.0036/YES	0.0005/YES
	pollution level indicator	0.2011/NO	0.0066/YES	0.0030/YES
	health advice	0.0910/YES	0.1561/NO	0.3175/NO
	social networking	0.2516/NO	0.0012/YES	0.0242/YES
	family tracking	0.2310/NO	0.0001/YES	0.0112 /YES
	automatic payment	0.0019/YES	0.0000/YES	0.0000/YES
	automatic geo-tagging	0.4621/NO	0.0105/YES	0.0908/YES
	automatic Facebook check-in	0.0493/YES	0.0010/YES	0.0820/YES
All the services	Max Payment	0.4684/NO	0.3953/NO	0.3146/NO

From the above analysis it can be observed that there is no significant dissimilarity of preferences between same user level of different classifications. But statistically significant differences in preferences are present when considering two different levels of users from same classification. In Table 7.21, the test result shows that there is significant dissimility present between high and low level users of knowledge-based class, when the preferences are:

- Basic cellular-only location capability
- GPS based positioning capability
- Hybrid high accuracy positioning capability
- Emergency service
- Advertising service
- Health advice service
- Automatic payment
- Automatic Facebook check-in

From the Table 7.14, Table 7.15 and Table 7.18, it can be observed that there are differences of choices in terms of paymnets and importance between high and low level users of the knowledge-based class. But the differences between user classes here depends on service, e.g., high level users belonging to knowledge-based class are more willing to pay for services like emergency alert services and automatic payments, while low level knowledge-based users are willing to pay more for advertising and automatic Facebook check-in. The differences in terms of importance of technology can be observed among the high and low level users of knwledge-based class, e.g., indoor positing is more important to high level users (Table 7.18). From such analysis, it can be infered that the background of users has a significant impact on the choices they are making, which means while paying for a location based service, high level knowlegde-based users are not willing to pay for what they know to be already state-of-the-art (e.g., basic cellular-only location capability), and the services which need more effeciency and in research stage are more important to the high level knowledge-based users (e.g., indoor positioning).

The above discussion proves that our classification is useful while designing location based services applications. LBS designers should consider the background of the target user while designing applications. It could also mean that LBS designers targeting users with higher knowledge in the field of wireless localization need to put an additional effort to create added value to such users and to find out which personalized services may be best appealing to a specific user class. Therefore, “User Classification” can be added as a small building block for the bridge of cognitive positioning paradigm of tomorrow, illustrated in the Figure 7.13.

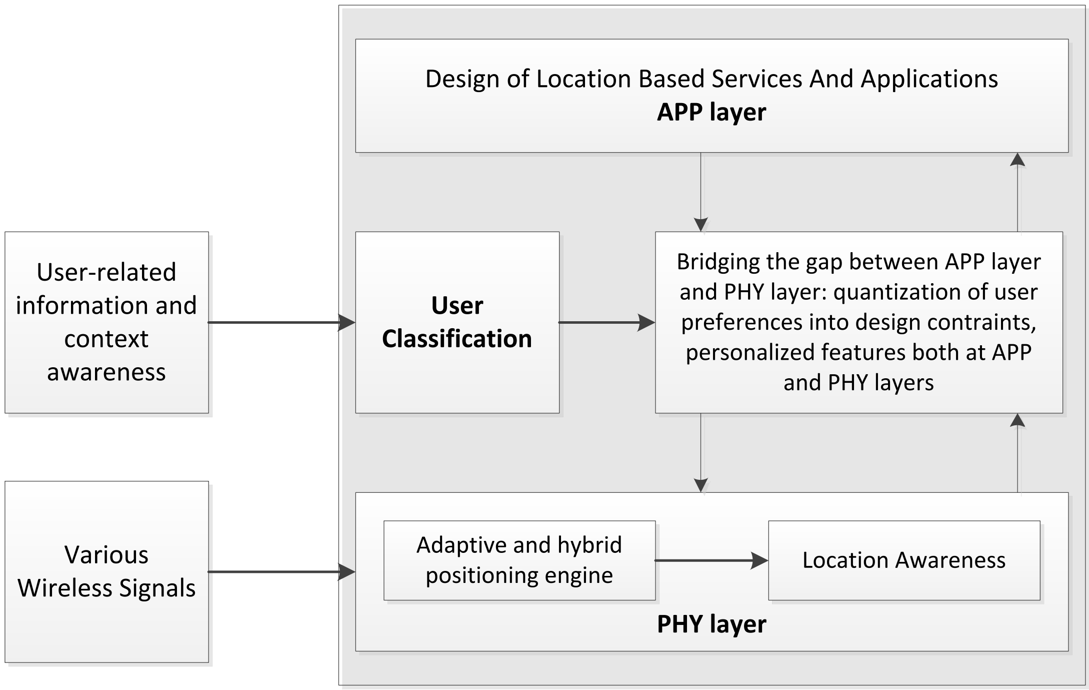

Figure 7.13: Illustration of the cognitive positioning paradigm.

In the Figure 7.13, The application (APP) and physical (PHY) layers are typically completely disjoint, and the APP layer builds upon the PHY layer, meaning that according to the achievable accuracy level coming from the used positioning technology, certain LBS are enabled. For example, three of the major underlying positioning technologies nowadays are the Global Navigation Satellite Systems (GNSS), cellular-based positioning and WLAN-based positining. While the first one offers the best positining accuracy we can achieve in outdoor environments, the latter two are gaining more and more interest in both outdoor urban and indoor scenarios. Thus, the hybridization solutions between different technologies are the answer to the future seamless outdoor-to-indoor localization. In a cognitive approach, as illustrated in Figure 7.13, additional user-related and context awareness information can be inserted into the positioning chain, in order to enhance both the provided LBS and the positioning solution desired by a particular class of users. Thus, there will be a bi-directional flow of information between the APP and PHY layers, in such a way that the overall provided solution (both in terms of technical and commercial features) is best customized to the users' needs and preferences.

Chapter 8

Conclusions and open directions

The future of Location Based Services relies on the current users' wishes, interests and appreciation towards the technology. The aim of the thesis was to conduct a quantitative analysis for today's user's perception, focusing on Location Based Services through a set of questionnaire and determine whether such information can facilitate the designer's decision-making towards future LBSs.

Our two phase quantitative analysis included: 1) the classification of users in terms of knowledge, privacy concern, usage and 2) the correlation among classes and their preferences. According to the analysis, it can be clearly observed that user's background class has significant impact on the preferences and that the technical knowledge regarding location technologies is an important quantitative factor which may differentiate between classes of users. From the study, a fair amount of dissimilarity of preferences depending on the features can be observed between high and low level users of knowledge-based class. The analysis also showed that there is little or no correlation between the user classes, but there is a high similarity between the user classes in terms of preferences. For example, the users from high level knowledge-based class have the same level of preferences as the high level usage-based class users.

Our study also showed that there is high similarity between users' classes while choosing the important feature of positioning. For example, the most appreciated feature was the location accuracy and availability regardless of the background user class. But an exception was also observed in choosing the feature for knowledge-based class. Indoor positioning accuracy was acknowledged by the high level knowledge-based class users, which justify the significance of the user classification.

An interesting finding of our study was that the high knowledge-based class users are less willing to pay when a bundle of LBSs is offered in comparison to the other user classes. From our analysis, it was also observed that the top features in a location enabled mobile, for all the users regardless of their user class, are: "High accuracy of location estimation", "user friendly interface", "continuous location availability" and "small delays". And the least important features are: "size of the mobile device", "light weight of the mobile device" and "device design".

According to the analysis result, most of the users are concerned about their privacy but while considering the knowledge class and usage class, most of the users reside in the average or low level. This illustrates that there is plenty of space for improvement while designing the LBS application in a way that users are more willing to use and learn. It can be also inferred from the analysis that the design of application should be adaptive. That means that, the design should not depend on the static data found from the analysis because users knowledge and usage level may evolve over time. So, taking the user's degree of knowledge into account when designing a service should be done in a flexible way, in the sense that the design should evolve over time to follow the changes in users' knowledge.

The future work of the quantitative analysis can be perceived from two viewpoints such as designing the survey and analyzing the results. In case of the survey design, the survey can be more adaptive, e.g., if the survey is divided into different sections as knowledge-based, privacy-based, etc.; the later sections of questions may vary depending on the previous section. In this way, the classification process would be more accurate and the analysis can be done in a more efficient way. From the analysis point of view, this thesis mostly covers the user preferences regarding LBS by the different user classes and only includes a comparison between the knowledge-based class and usage-based class. As a future continuation of this study the “knowledge-based class and privacy concern-based class” and “privacy concern-based class and usage-based class” could be compared and correlated.

Finally, it can be concluded that these user perceived inputs facilitate the application designers in decision makings and in taking the technology to precise and accurate level. Eventually, the success of the quantitative model from the end-user perspective will depend on the targeted LBS and its spread among mobile users.

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Appendix

Survey Questionnaire [76]

Our survey can be found at: http://www.webropolsurveys.com/poslbssurvey.net (key: poslbssurvey) and it is still open for volunteer answers.

Purpose: The purpose of this survey was to gather information through a set of questions in order to be able to characterize the user needs, behaviour and applications in the context of Location Based Services (LBS). An additional objective is to determine whether such information can facilitate the engineering decision-making towards future Location Based Services. This work represents a part of a Master Thesis to be publicly presented at Tampere University of Technology. The published work will also be available to all those that answer the questions and give their email address at the end of the survey.

Positioning or **location** refers here to the ability of a mobile device to compute and report the user's location on a map. Location-Based Services (LBS) refer to the applications available on the user's mobile device that are employing the user positioning information.

Note! *Your responses will be treated with confidence and all answers given will be non-attributable and will only ever be used at the aggregate level during the reporting purpose. We shall not supply your information on to third parties*

The published work will also be available to all those that answer the questions and give their email address at the end of the survey. ***The email information is optional***

The survey should take about 30 minutes
(* = mandatory selection)

Q#1: Counntry of Residance

Q#2: Age
below 20
between 21 - 25
26 - 30

3-5
31 - 35
41 - 45
45 - 50
above 50

Q#3: Gender
Male
Female

Q#4: What is your current work status
Full-time working/employed
Part-time working
Unemployed
Other

Q#5: Last Completed Degree
BSc
MSc
PhD/Dr Tech
Others

Q#6: What are the most important features, from your point of view, of a mobile terminal with location capabilities? (Maximum 3 choices including 'other') *
High accuracy of your location estimate
Low cost of the mobile device
Small size of your mobile device
Lightweight of your mobile device
Delay in starting an application
User-friendly interface
Device design
Large screen size
Continuous location capability
Other – Please Specify

Q#7: Number of wireless devices (e.g. mobile phone, GPS, iPod, iPad,etc) owned by you
None
1

2
3-5
>5

Q#8 How much is your average monthly fee for mobile subscriptions (including mobile phone fees, web-based services on your mobile phone if any, fees on your mobile to access online data such as navigation maps)
below 5 EUR/month
between 5 and 10 EUR/month
between 10 and 25 EUR/month
between 25 and 40 EUR/month
between 40 and 60 EUR/month
more than 60 EUR/month

Q#9: According to your self-evaluation, what is your level of familiarity with the technical features of the following systems that can be used for navigation?*					
	None	Little	Moderate	Good	Excellent
GPS					
Galileo					
GLONASS					
COMPASS					
EGNOS					
WLAN					
WCDMA					
LTE					
UWB					
Bluetooth					
DTV					

Q#10: Please fill in the answers you believe to be correct to the following assertions. Use only your current knowledge (no additional Internet search); these assertions are only used to determine your current familiarity with positioning techniques; there is no ‘right’ or ‘wrong’ level of familiarity			
	True	False	Don’t Know
There are currently 5 IOV Galileo satellites on sky			
Wi-Fi signals can be used for indoor positioning			
Now-a-days typical accuracy of positioning (outdoors) via your mobile phone is at cm level			

GLONASS constellation has 24 active satellites			
Compass system is a fully operational global navigation system as of today (Oct 2012)			
TV signals belong to the so-called Signals of Opportunity and can be used for positioning purposes			
Your position can always be tracked to few tens of meters accuracy by your mobile operator			
In the context of GNSS, GSA stands for the Global mobile Suppliers Association			
If your Bluetooth is 'ON' on your mobile device, your position will be estimated more accurately by any Bluetooth-enabled mobile device			
Code phase measurements can provide much higher accuracy than carrier phase measurements in GNSS			
Multiple Access Scheme used in Galileo is CDMA			
The only multiple access scheme used in Glonass is CDMA			
Ultra wide-band (UWB) signals are very accurate for indoor positioning			
Zigbee consumes more power than Bluetooth connection			
Cooperative positioning means user mobile exchanging location data with nearby mobiles			

Q#11: How often have you used each of the Location Based Services shown below? (Choose the most frequent that applies)				
	At least few times per month	Few times per year	Few times in my life	Never
Getting navigation directions from your car navigator				
Getting navigation directions from your mobile phone				
Using a mobile tracker (e.g. location-enabled clock, bracelet, etc) to track a pet or a member of your family				
Using a sport tracker (e.g. tracking and monitoring your bike routes, etc)				
Using a mobile or web service for				

real-time urban transportation service tracking (e.g. to see when the next bus is coming to your stop)				
Using a mobile or web service for real-time tracking of your assets/belongings (e.g. Laptop, luggage, car, etc)				
Using location tracking services while gaming online				
Using Location based advertisement in a social network, e.g. facebook				

Q_12: How often do you clear your wireless device cache or memory?
-Daily
-Weekly
-Monthly
-Once or few times a year
-Never

Q_13: Have you ever modified the privacy settings to the highest level other than the default privacy settings provided in the following cases:				
	Yes (To Maximum Level)	Yes (To Intermediate Level)	No	N/A (Not own a mobile device)
On your mobile phone				
On your email account				
On your LinkedIn account				
On your facebook account				

Q_14: How often do you log out after logging into a online service or online webpage (e.g. online shopping, online emailing tools, etc)
-Always
-Often
-Seldom
-Never

Q_15: What is the status of the following wireless connections of your wireless phone?				
	Always ON	Typically ON	ON only when needed	Don't have/Don't use/Don't Know
Bluetooth				

Zigbee				
WLAN				
WWAN				

Q_16: Is the 'Automatic Update' option enabled in your cellular phone? *
-Yes
-No
-Don’t Know

Q_17: How often do you use unprotected WLAN connection in public places?
-Always when available
- Only when travelling and there is no secure free alternative
-Very Seldom
-Never

Q_18: How often in the past have you agreed to let a web or mobile application or service to use your personal data (e.g. your location, contact information, etc)?
-Always
- Frequently
- Only when compulsory for completing a operation
-Never

Q_19: What would you do in the following scenario: "Continuous positioning data sharing to the provider might enhance the accuracy but increase the data transfer cost on the other hand, sharing positioning data while needed might decrease the data transfer cost but at the same time decrease the accuracy level" *
-I would agree to share my position information always
- I would agree to share my position information occasionally (e.g. when traveling)
- I would forbid the sharing of my position information always
-Don't know/No comment

Q_20: What would you do in the following scenario: "Allowing to share your position information with other nearby user devices (in an anonymous way) would increase your own position accuracy estimation most of the cases, but it will slightly increase the battery consumption of your own device" *
-I would agree to share my position information always
- I would agree to share my position information occasionally (e.g. when traveling)
- I would forbid the sharing of my position information always

-Don't know/No comment

Q_21: What would you do in the following scenario: "An update of your Location Based Service application on your mobile is available, offering better services. If you update it, there is a high risk that you'll lose all the LBS data previously saved by your application" *
-Yes, I would update it
- I would update it only if I had a clear description of service enhancements and a clear advantage over current services
- No, I would not update it
-Additional comments:

Q#22: Assuming all other mobile features equally the same, how much are you willing to pay for a mobile phone with positioning capabilities compared to the basic price x of the same mobile without any positioning (choose only one, the maximum that applies): *						
	less than (x+10) EUR	less than (x+30) EUR	less than (x+50) EUR	less than (x+80) EUR	less than (x+100) EUR	less than (x+150) EUR
Basic positioning capability (e.g. cellular based, accurcay of few hundred meters)						
GPS-based positioning capability (meter accuracy outdoors, no coverage indoors, long latency at start-up)						
Assisted-GPS positioning capability(meter accuracy outdoors, limited coverage indoors, fast position computation at start-up)						
Hybrid high-accuracy positioning (combination of GPS, WLAN , cellular, meter accuracy both indoors and outdoors and 3D positioning)						

Q#23: Assuming that you want to buy a new mobile device with location capabilities, how do you appreciate the following features on a scale of 0 to 5? (0=Don't know 1 = Not Important/Don't care, 2=Low importance; 3=Somehow important; 4=Important; 5=Very important)

Please avoid checking all as 'very important'; try to find at least 3 features which are of moderate or low or no importance for you. *

	0	1	2	3	4	5
Very high accuracy of the location position (e.g. average errors less than 1 m) indoors						
Very high accuracy of the location position (e.g. average errors less than 1 m) outdoors						
Moderate accuracy of the location position (e.g. average errors less than few tens of m) indoors						
Moderate accuracy of the location position (e.g. average errors less than few tens of m) outdoors						
Very high availability of the position estimate (e.g. to be able to receive your location estimate in more than 98% cases) indoors						
Very high availability of the position estimate (e.g. to be able to receive your location estimate in more than 98% cases) outdoors						
Moderate availability of the position estimate (e.g. in more than 70% cases) indoors						
Moderate availability of the position estimate (e.g. in more than 70% cases) outdoors						
Short delays (e.g. time to start a certain location-based application on your mobile)						
User friendliness (e.g. ease of use of a certain location-based application on your mobile device)						
Small amount of manual settings (e.g. adjustments in the application settings according to location to be done as much as possible automatically)						
Personalized features (e.g. to be able to set manually certain user profiles, such as pedestrian/car; office/travel and certain user parameters, such as maximum speed, user height for step size adjustments in positioning, typical placement of phone: pocket/bag, etc)						

Q#24: Assuming it were technically possible, to which level of detail would you like your position to be displayed?				
	Position displayed with a street level of detail (about 10 m)	Position displayed with a block level of detail (about 1 m)	Position displayed with a sub-step level of detail (few tens of cm)	Position displayed at cm level accuracy (1 cm or less)
Outdoors, rural				
Outdoors, urban				
Indoors				

Q#25: In order to have your location estimation engine working continuously on your mobile device (and not only on demand), which of the following allowances would you be willing to make? (Please choose at least one) *			
	Yes	No	Don't Know
I would accept a lower battery life			
I would accept a slower time in opening new applications on my mobile device			
I would accept a heavier device			
I would accept a bigger device (higher size)			
I would accept a less elegant device design			
I would accept a less user-friendly device			
I would accept a more expensive device			

Q_26: In cooperative positioning (for example user mobile exchanging location data in a safe and private way with nearby mobiles) significant accuracy and availability gains can be achieved. What is the acceptable loss in battery time that you would be willing to accept for a better positioning performance? (choose the maximum that applies) *
-Max 1 minute loss in battery duration (for example, if your battery in non-cooperative mode lasts 120 minutes, you will be OK with a 119-minute battery time in the cooperative mode)
-Maximum 5 minutes loss in battery duration
- Maximum 10 minutes loss in battery duration
-Maximum 15 minutes loss in battery duration
-Maximum 30 minutes loss in battery duration
-Maximum 45 minutes loss in battery duration

Q#27: How much would you be willing to pay monthly on top of your mobile subscription for the following services on your mobile phone, assuming they were available to buy: *						
	Nothing/Not interested in this application	less than 1 EUR/month	less than 2 EUR/month	between 2 and 5 EUR/month	between 5 and 10 EUR/month	between 10 and 20 EUR/month
an emergency alert service that will inform you of any present or forecast disturbances (e.g. floods, crisis, fire, earthquake) in the neighbourhood of your location						
an LBS-based advertising service (for example giving you a list with all nearby shops having a desired item and a list of ther prices/specifications)						
a public transport routing service (for example showing you several routes between point A and point B via public transport, what are the fees to get from point A and point B, which is the fastest route and what is the status of the traffic: fluent/congested)						
a pollution-level indicator service (for example showing what is the air and water quality of the town/district you are in and which are the health risks associated with that quality level)						
a personalized health-advice service: for example						

based on your medical history and physical activity levels, you will get daily recommendations about the healthy level of exercise/physical activity to achieve and indications about nearby places where you can perform physical activity (gyms, swimming pools, etc)						
a social networking service: for example, based on your pre-defined hobbies and interests, you will get (on demand) sms alerts with coordinates of other people with similar hobbies/interests that have subscribed to this service						
a LBS service about the location of your children, close family & friends, assuming they gave the consent to be located/tracked by you						
Checking automatically or automatic payment for a museum, train, theater show, etc, based on your mobile device with location capabilities (this would decrease the queues and waiting times)						
automatic geo-tagging of photos taken with mobile device						
Facebook- 'check-in' application (to be able to 'check-in' at the location you are)						

Q#28: How much as a maximum amount would you be willing to pay in total as monthly fee for all the location-based applications mentioned at Question 27 (assuming they could come as a joint pack of services) *
EUR:

Q#29: Do you have a smartphone? (Smartphone is a phone that allows you to connect to the internet and install 3rd party applications. It also typically has a touchscreen) *
Yes
No

Q#30: How long time have you used a smartphone? *
Never
Less than 6 months
Between 6 months and 1.5 years
Between 1.5 years and 5 years
More than 5 years

Q#31: How important are the following technical features of your mobile phone (1 not important … 5 very important) *					
	1	2	3	4	5
large display screen					
small size					
long battery time					
Bluetooth chipset (capacity of Bluetooth connection)					
WLAN chipset					
QWERTY keyboard (i.e., small keyboard similar with laptop keyboards)					
Touchscreen					
GPS chipset (capacity of positioning without network coverage or GPRS connection)					
Some positioning capabilities (e.g. network based)					

Q#32: Wireless sensors attached to your mobile device together with your location information can in the future offer significant information about your physiological parameters (heart beat, skin dryness, fitness conditions, blood pressure, etc.) and can help in personalized advices to increase your well-being. Assuming that you can get such personalized health advices for free, how willing would you be to carry your mobile device at

your belt or close to your body (not in a bag or purse) continuously during the day? The scale is from 1 (not willing at all) to 5 (extremely willing). *
1
2
3
4
5

Q#33: Have you ever installed a Location Based service or application on a mobile phone? *
Yes
No

Q#34: Which billing scheme would you prefer for each of the following application categories? *

	Subscription-based (e.g. monthly, yearly, etc.)	Pay-per-download	Free but with in-app advertising	Up-selling content packs (free installation of the basic version of the application but paying for additional content)	No preference/all equal
Emergency					
Transport					
Personal navigation					
Social networking					
Asset tracking					
Sports tracking					
Health monitoring					

Q_35: How often do you read the reviews or comments of others before you decide to download an application or pay for a service? *
-Never

-Seldom
-Often
-Always
-Don’t know

Q_36: If you read reviews before installing an application, what is the minimum rating an application should have for you in order to download it? (from 1 star = very poor reviews to 5 stars = very good reviews and 0 = don't care/don't read reviews) *
1 star
2 stars
3 stars
4 stars
5 stars
0

Q_37: What type of features regarding localization would you expect to be available on a smart mobile device in 2017? (check all that apply; do not check if a feature is unknown) *
Satellite-based navigation/positioning engine
Assisted GNSS navigation engine (e.g. positioning via satellite but aided by cellular network)
Indoor 3D navigation (e.g. including floor detection and indoor maps)
Location-Based social networking applications (e.g. meeting nearby friends, finding nearby events such as concerts, gatherings, etc)
Location-Based applications related to health (e.g. health or fitness advices according to your cardiac activity and movement patterns , diet recommendations according to your location, etc)
Location-based interactive games
Location-based shopping service (e.g. recommendations about where to find the nearest shop selling your favourite cheese brand, etc)
Emergency alerts (e.g. alerts about crisis, floods, fires in the neighborhood of your location)
Sports tracker services (e.g. running/walking trajects statistics, etc)
Location-based toll road (e.g. paying highway fees according to where you drive)
Environmental indicators based on location (e.g. pollution level, water quality, humidity level, toxic emission levels, etc)
Other (Please specify):

Q#38: Are you a student of TUT? And willing to give your student number in order to get the bonus points in case you are registered to a course at Tampere University of Technology that is associated to this survey. *
Yes
No